COMPRESSED AIR

AND EVERYTHING PNEUMATIC.

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THE MOISTURE IN THE ATMOSPHERE

ITS EFFECT ON THE OPERATION OF COMPRESSED AIR MACHINERY, ESPECIALLY AIR BRAKE, MULTIPLE-UNIT TRAIN CONTROL AND TRAIN SIGNAL SYSTEMS.

By H. M.-Prevost Murphy.

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Ever since the introduction of compressed air into the railway and commercial fields, much imperfect operation and many failures have resulted from the presence of condensed moisture in vital parts of the apparatus used. Long practical experience and careful, scientific investigation have, however, demonstrated that all difficulties arising from this source may be reduced to comparative insignificance, if not entirely eliminated, by properly installing the various devices concerned. The objects of this article are to point out the physical laws involved in the subject, to explain the most approved methods of securing "dry air" for use in any system, and to establish a correct method for determining the amount of moisture that is deposited by compressed air under various operating conditions.

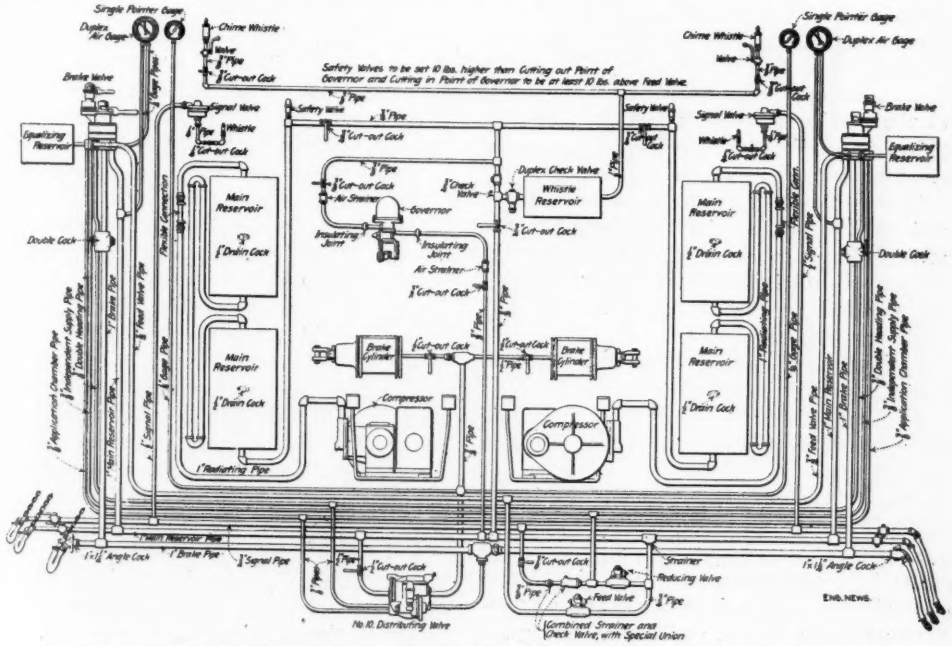


FIG. 1 DIAGRAMMATIC ARRANGEMENT OF A WESTINGHOUSE AIR-BRAKE EQUIPMENT FOR ELECTRIC LOCOMOTIVE.

Although the troubles resulting from "wet air" are of much consequence in stationary work, where complicated pneumatic machines are used, it is seldom that any very serious accidents occur in this field; loss of time and broken tools usually being the extent of the damage done. It is in the operation of modern railways, particularly electric systems, where the problem assumes a most important nature. This will be readily appreciated when it is remembered that on a large number of such roads the block signals, interlocking switches, multiple-unit control equipments and automatic brakes are all operated by compressed air.

Of course, the evil effects of excess moisture, if permitted to enter any of the systems referred to, are readily imagined if indeed not already familiar to the reader. In warm climates, where freezing weather is never experienced, any water passing through and deposited in the various valves and passages is not a positive source of danger, although it may cause extremely sluggish and unsatisfactory operation, but it will inevitably produce a much more rapid deterioration of the apparatus than would otherwise be the case. On the other hand, in latitudes where freezing does occur for even short periods of time, any water which is deposited in these systems is not only liable to burst pipes and valves, but also to so obstruct the ports and passages of the various devices and even to so entirely block the action of the moving parts, that failures from this source are, unfortunately, of too frequent occurrence during the winter months.

In order to clearly understand the situation and to obtain a useful knowledge of the methods employed in practice to obviate the difficulties experienced from the presence of the moisture in the atmosphere, it will be necessary to first investigate the simple unvarying physical laws which govern the case. These laws may be stated as follows:

(1) Atmospheric air always contains some moisture, which it absorbs from rivers, creeks, rainfall, etc.

(2) The amount of moisture present in the atmosphere depends on local conditions and on the weather.

(3) The maximum amount of moisture that pure air can contain depends only on its temperature and pressure, and has an unvarying value for each condition.

(4) The higher the temperature of the air, the greater is the amount of moisture that it can contain.

(5) The higher the pressure of the air, the smaller is the amount of moisture that it can contain.

(6) When air is compressed, its temperature rapidly rises to a high point, which depends on the design and speed of the compressor and the delivery pressure worked against.

(7) The rise of temperature due to the compression of the air, in all cases found in practice, far more than offsets the opposite effect of the rise of pressure on the moisture carrying capacity of the air.

As a result of these laws, it is easy to see how water is deposited by compressed air as it passes from the pump to the various portions of the system. Suppose that a certain amount of atmospheric air enters a compressor and that this air is at the saturation point, that is that it contains all the moisture possible at the existing outside temperature and pressure. Then as this air is compressed as stated in law (7), its moisture carrying capacity very rapidly increases, for the rise of temperature more than offsets the opposite effect of the rise of pressure, consequently all the moisture in the air is still retained by it and passes with it into the main, or storage, reservoir and its connecting pipes. Now if this air is permitted to pass from here into the various parts of the system before being cooled to the outside temperature, it will, of course, carry more moisture with it than it is capable of holding in suspension when the temperature finally drops to the normal point, and this excess quantity will then be deposited, because, the pressure being high, the air cannot hold as much moisture as it did at the same temperature and only atmospheric pressure (law 5).

Now, as will be readily seen, in order to reduce to a minimum the evil effects of this water, which is bound to appear in any compressed air system under average weather conditions, it is most desirable to cause the air to deposit all of its excess moisture in the main reservoirs, from which it may be easily removed by the drain cocks which should always be provided for that purpose. In order to accomplish this completely, it is merely necessary to *cool the air to the outside temperature before it leaves these reservoirs.* This may easily be done by using a sufficiently

long air discharge or radiating pipe between the pump and the main reservoirs which should be of large capacity not only to provide for an ample storage of air but also in order to allow the compressed air to remain in them for a length of time sufficient to permit the superfluous moisture to be completely deposited and to insure a liberal supply of cold air at all times. The use of pressure reducing valves between the main reservoirs and the rest of the system is sometimes considered of benefit in securing "dry air," but as such devices simply cause some of the moisture to be deposited in the pipes near at hand (not in the main reservoirs) instead of in the more remote parts of the system, the merits of this method are extremely doubtful and it should never be resorted to unless drain cups are placed in the pipes concerned, for excess water vapor once allowed to pass from the main reservoirs will

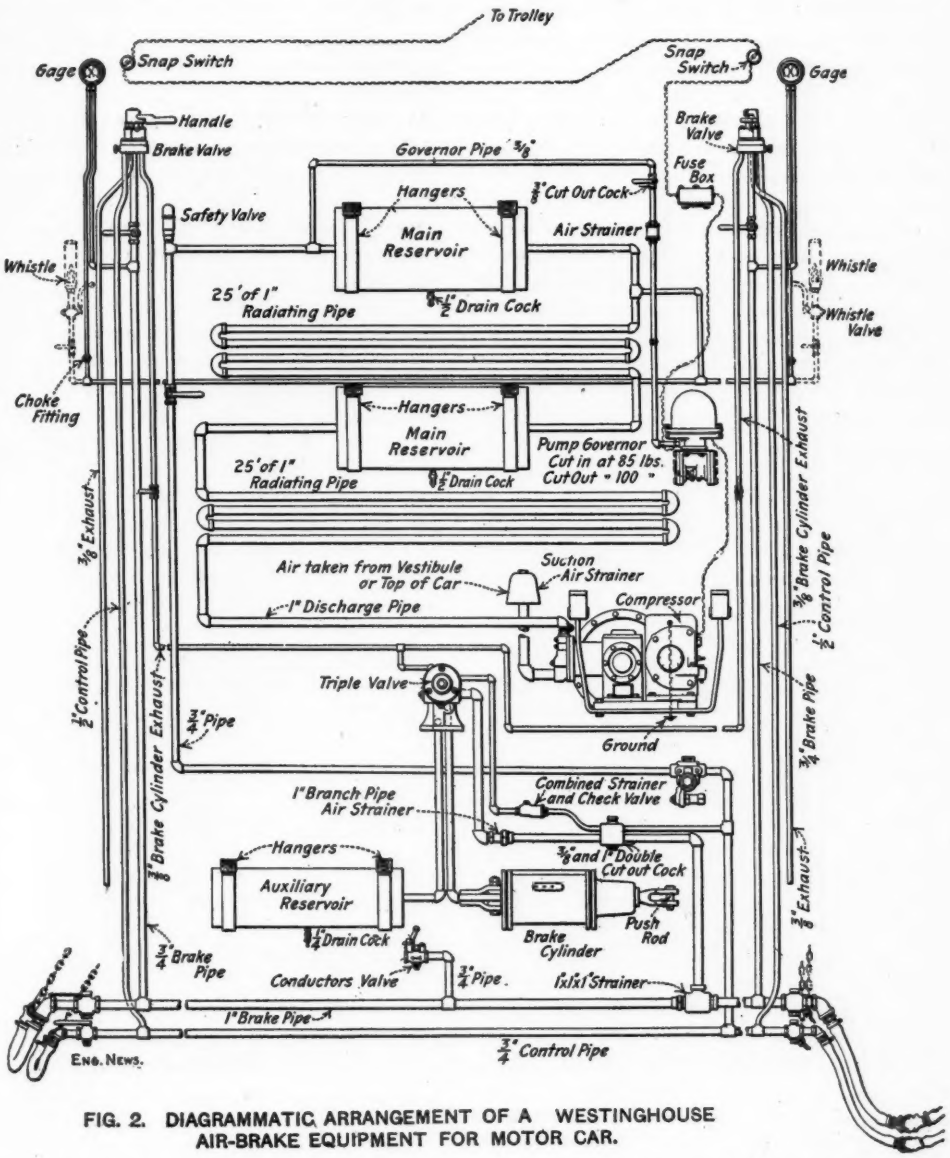


FIG. 2. DIAGRAMMATIC ARRANGEMENT OF A WESTINGHOUSE AIR-BRAKE EQUIPMENT FOR MOTOR CAR.

surely cause ultimate trouble unless it be properly trapped and regularly drained off.

In stationary work where the air is sometimes reheated before being used, in order to increase the efficiency of the devices operated by it, no trouble ought ever to be experienced from the moisture, but in all other installations, including those on railways, long radiating pipes should always be employed. Of course it is true that even if the compressed air be cooled to the existing outside temperature, before leaving the main reservoir, some moisture may be deposited in the rest of the system, if a drop of the outside temperature occurs, but the amount of water thus produced must obviously be very small, and appears merely as little beads on the interior walls of the various devices. It is seldom that any trouble is experienced from this source alone. Moreover, although compressed air may be properly dried before leaving the main reservoirs, some moisture may be temporarily deposited when the air is subsequently expanded to lower pressures, as the moisture carrying capacity of the air is usually affected more by the drop in temperature, resulting from the expansion, than by the drop in pressure, but when the air again attains the outside temperature, the moisture thus deposited will be reabsorbed if it is freely exposed to the compressed air.

In order to show how installations should be made so as to secure "dry air" for use in any system, piping diagrams of modern Westinghouse air-brake equipments for street railway and interurban cars and electric locomotives are illustrated by Figs. 1 and 2, in both of which the radiating pipe is clearly indicated. For stationary plants, such as automatic switch and signal stations, similar radiating systems should be employed, in addition to which water jacketed compressors should be used whenever possible, not only to secure a high mechanical efficiency but also to aid the radiating pipes in the performance of their duty. As a general proposition in railway work, 50 to 70 ft. of this pipe is considered the correct amount, and, when used, no trouble whatever should be experienced with wet air, if the reservoirs are carefully drained every day or, in moist climates, after each long run.

In order to determine exactly what percentage of moisture pure air can contain at various pressures and temperatures, to ascertain how low the "relative humidity" of the atmosphere must be in order that no water will be desposited in any part of a compressed air system, and also to find to what temperature air drawn from a saturated atmosphere must be cooled in order to cause the deposition of moisture to commence, the following discussion is necessary, as no correct method has heretofore been published to cover the situation.

In order to obtain the desired information, is it only necessary to remember a well-known physical law which covers the case of most mixed gases with great exactitude, for water vapor is merely a gas. The law is known as "Dalton's Law of Gaseous Pressures," and may be stated as follows:

"Every portion of a mass of gas enclosed in a vessel contributes to the pressure against the sides of the vessel the same amount that it would have exerted by itself had no other gas been present.

In other words, the total pressure exerted against the interior of a vessel by a given quantity of a mixed gas enclosed in it is the sum of the pressures which each of the component gases would exert separately if it were enclosed alone in a vessel of the same bulk, at the same temperature.

This law applies to mixtures of pure air and saturated water vapor, and in order to determine the maximum weight of moisture that can be held in suspension by one pound of pure air at any temperature and pressure it is merely necessary to proceed as outlined in what follows.

Letting p_2 represent the absolute pressure in lbs. per sq. in., and t the temperature Fahrenheit, the weight in lbs. of 1 cu. ft. of pure air is known to be equal to:

$$2.698192 \times \frac{p_2}{459.2 + t}.$$

Also letting N equal the volume in cubic feet of one pound of pure air at the temperature, t, and pressure, p_2, there results the equation:

$$1 = N \times 2.698192 \times \frac{p_2}{459.2 + t} \quad \ldots\ldots \text{(Equation 1)}$$

Now w, the weight in lbs. of 1 cu. ft. of saturated steam (or water vapor) at the temperature, t, and corresponding absolute pressure, p_1, in lbs. per sq. in., has been shown by the author to be accurately expressed, in accordance

with the average values given by the most reliable authorities, by the following equation, for all conditions:

$$w = \frac{p_1}{459.2 + t}\left(1.6494 + \frac{0.248\,t}{850 - t}\right)$$

and by letting W represent the weight of N cubic feet of saturated steam at the temperature, t, and pressure, p_1, there results the equation:

$$W = \frac{N p_1}{459.2 + t}\left(1.6494 + \frac{0.248\,t}{850 - t}\right) \ldots \text{(Equation 2)}$$

By taking the N cubic feet of pure air at pressure, p_2, and the N cubic feet of saturated steam at the pressure, p_1, and forcing them both into one vessel of volume, N, keeping the temperature constant at the value, t, the resulting pressure, by Dalton's law, will be $p_2 + p_1$, which may be placed equal to p, thus:

$$p = p_2 + p_1 \ldots\ldots\ldots\ldots\ldots\ldots \text{(Equation 3)}$$

W will, of course, represent the maximum weight of water vapor that 1 lb. of pure air

TABLE I.—A TABLE WITH FORMULAS GIVING THE WEIGHTS, IN LBS., OF 1 CU. FT. OF DRY AIR, OF 1 CU. FT. OF SATURATED STEAM OR WATER VAPOR AND THE MAXIMUM WEIGHT OF WATER VAPOR THAT 1 LB. OF PURE AIR CAN CARRY AT ANY PRESSURE AND TEMPERATURE. (Copyright, 1906, by H. M.-Prevost Murphy.)

The Values K and H Being Given in the Table for Various Temperatures, t, in Fahrenheit Degrees, the Formulas Are:

Weight of 1 Cu. Ft. Saturated Steam $= \frac{1.325271\ K\ H}{459.2 + t}$ (Exactly).

Weight of 1 Cu. Ft. Saturated Steam $= \frac{1.3253\ K\ H}{459 + t}$ (Approximately).

H Being Equal to 2.036 × (Gage Pressure + Atmos. Pres., in Lbs. per Sq. Inch).
H, K and t, Having Corresponding Values as Given in Table

Weight of 1 Cu. Ft. Pure Dry Air $= \frac{1.325271\ M}{459.2 + t}$ (Exactly).

Weight of 1 Cu. Ft. Pure Dry Air $= \frac{1.3253\ M}{459 + t}$ (Approximately).

Weight of 1 Cu. Ft. Pure Dry Air $= \frac{2.698192\ P}{459.2 + t}$ (Exactly).

Weight of 1 Cu. Ft. Pure Dry Air $= \frac{2.7\ P}{459 + t}$ (Approximately).

M Being the Absolute Pressure Measured in Inches of Mercury;
P Being the Absolute Pressure Measured in Lbs. per Sq. Inch.

Letting W = the Maximum Wt., in Lbs., Water Vapor, that 1 Pound of Pure Air Can Contain, when the Temperature of the Mixture is t, and the Total, or Observed, Absolute Pressure in Lbs. per Sq. Inch is P, the Value of W, is:

$$W = \frac{K\ H}{2.036\ P - H}\ \text{(Exactly)}.$$

The Values of K and H Corresponding to the Existing Temperature Being Given by the Table.

For Any Temperature the Value of K (the Ratio of the Wt. of a Volume of Saturated Stream to an Equal Volume of Pure Dry Air at the Same Temperature and Pressure) May Be Accurately Computed by the Following Formula:

$$K = 0.6113 + \frac{0.002\ t}{850 - t}\ \text{(Exactly)}.$$

Note.—The Results Obtained by the Use of Any of the Above Formulas Agree Exactly with the Average Data for Air and Steam Weights as Given by the Most Reliable Authorities and Careful Experiments, for All Pressures and Temperatures, the Value of K Being Correct for All Temperatures up to the Critical Steam Temperature of 689° F.

TABLE GIVING THE VALUES OF "K" AND "H" CORRESPONDING TO EACH FAHRENHEIT DEGREE OF TEMPERATURE FROM 30° BELOW TO 434° ABOVE ZERO.

Temp.	Values of K	Values of H
-30	6082	0099
-29	6083	0105
-28	6084	0111
-27	6085	0117
-26	6086	0123
-25	6087	0130
-24	6088	0137
-23	6089	0144
-22	6090	0152
-21	6091	0160
-20	6092	0168
-19	6093	0177
-18	6094	0186
-17	6095	0196
-16	6096	0206
-15	6097	0216
-14	6098	0227
-13	6099	0238
-12	6100	0250
-11	6101	0262
-10	6102	0275
-9	6103	0288
-8	6104	0303
-7	6105	0317
-6	6107	0332
-5	6108	0348
-4	6109	0365
-3	6110	0382
-2	6111	0400
-1	6112	0419
0	6113	0439
+1	6114	0459
2	6115	0481
3	6116	0503
4	6117	0526
5	6118	0551
6	6120	0576
7	6121	0603
8	6122	0630
9	6123	0659
10	6124	0690
11	6125	0722
12	6126	0754
13	6127	0789
14	6128	0826
15	6130	0862
16	6131	0900
17	6132	0941
18	6133	0983
19	6134	1028
20	6135	1076
21	6136	1122
22	6137	1172
23	6139	1224
24	6140	1279
25	6141	1336
26	6142	1396
27	6143	1458
28	6144	1523
29	6146	1590
30	6147	1661
31	6148	1734
32	6149	1811
33	6150	1886
34	6151	1960
35	6153	2039
36	6154	2120
37	6155	2203
38	6156	2292
39	6157	2382
40	6158	2476
41	6160	2572
42	6161	2673
43	6162	2778
44	6163	2883
45	6164	2998
46	6166	3109
47	6167	3227
48	6168	3350
49	6169	3477
50	6170	3608
51	6172	3743
52	6173	3883
53	6174	4027
54	6175	4176
55	6177	4331
56	6178	4490
57	6179	4655
58	6180	4824
59	6182	4999
60	6183	5180
61	6184	5367
62	6185	5559
63	6187	5758
64	6188	5962
65	6189	6178
66	6190	6393
67	6192	6617
68	6193	6847
69	6194	7086
70	6196	7332
71	6197	7585
72	6198	7846
73	6199	8114
74	6201	8391
75	6202	8676
76	6203	8969
77	6205	9271
78	6206	9583
79	6207	9906
80	6209	1.024
81	6210	1.057
82	6211	1.090
83	6213	1.124
84	6214	1.159
85	6216	1.203
86	6217	1.242
87	6218	1.282
88	6219	1.324
89	6221	1.364
90	6222	1.410
91	6223	1.455
92	6225	1.501
93	6226	1.548
94	6227	1.597
95	6229	1.647
96	6230	1.698
97	6232	1.751
98	6233	1.805
99	6234	1.861
100	6236	1.918
101	6237	1.976
102	6238	2.036
103	6240	2.098
104	6241	2.161
105	6243	2.226
106	6244	2.294
107	6245	2.363
108	6247	2.434
109	6248	2.506
110	6249	2.579
111	6251	2.654
112	6253	2.731
113	6255	2.811
114	6256	2.892
115	6257	2.976
116	6258	3.061
117	6260	3.149
118	6261	3.239
119	6263	3.331
120	6264	3.423
121	6266	3.522
122	6267	3.621
123	6269	3.722
124	6270	3.826
125	6272	3.933
126	6273	4.042
127	6274	4.153
128	6276	4.267
129	6278	4.384
130	6279	4.503
131	6281	4.625
132	6282	4.750
133	6284	4.877
134	6285	5.008
135	6287	5.142
136	6288	5.279
137	6290	5.419
138	6291	5.563
139	6293	5.709
140	6294	5.859
141	6296	6.012
142	6298	6.169
143	6299	6.329
144	6301	6.490
145	6302	6.656
146	6304	6.827
147	6305	7.001
148	6307	7.178
149	6309	7.359
150	6310	7.545
151	6312	7.736
152	6313	7.929
153	6315	8.127
154	6316	8.329
155	6318	8.536
156	6320	8.748
157	6321	8.958
158	6323	9.177
159	6325	9.400
160	6326	9.628
161	6328	9.860
162	6330	10.10
163	6331	10.34
164	6333	10.59
165	6335	10.84
166	6336	11.10
167	6338	11.36
168	6340	11.63
169	6341	11.90
170	6343	12.18
171	6345	12.46
172	6346	12.75
173	6348	13.04
174	6350	13.34
175	6352	13.64
176	6353	13.96
177	6355	14.28
178	6357	14.60
179	6359	14.93
180	6360	15.27
181	6362	15.62
182	6364	15.97
183	6365	16.33
184	6367	16.68
185	6369	17.05
186	6371	17.43
187	6373	17.81
188	6374	18.20
189	6376	18.59
190	6377	19.00
191	6380	19.41
192	6381	19.83
193	6383	20.25
194	6385	20.68
195	6387	21.13
196	6389	21.58
197	6391	22.04
198	6394	22.51
199	6396	22.99
200	6398	23.48
201	6399	23.98
202	6400	24.48
203	6402	24.98
204	6404	25.47
205	6405	25.99
206	6407	26.53
207	6409	27.07
208	6411	27.62
209	6413	28.18
210	6415	28.76
211	6417	29.33
212	6419	29.92
213	6421	30.53
214	6423	31.14
215	6424	31.76
216	6426	32.40
217	6428	33.02
218	6430	33.67
219	6432	34.33
220	6434	35.01
221	6436	35.69
222	6438	36.38
223	6440	37.08
224	6442	37.80
225	6444	38.53
226	6446	39.27
227	6448	40.02
228	6451	40.78
229	6453	41.56
230	6455	42.36
231	6457	43.14
232	6459	43.95
233	6460	44.77
234	6463	45.61
235	6465	46.46
236	6467	47.32
237	6469	48.19
238	6471	49.08
239	6473	49.98
240	6475	50.89
241	6477	51.83
242	6479	52.77
243	6481	53.76
244	6484	54.69
245	6486	55.66
246	6488	56.67
247	6490	57.69
248	6492	58.71
249	6494	59.76
250	6496	60.81
251	6499	61.89
252	6501	62.97
253	6503	64.08
254	6505	65.21
255	6507	66.36
256	6510	67.49
257	6512	68.66
258	6514	69.85
259	6516	71.05
260	6518	72.26
261	6521	73.50
262	6523	74.73
263	6525	76.02
264	6528	77.30
265	6530	78.61
266	6532	79.93
267	6534	81.27
268	6537	82.62
269	6539	84.00
270	6541	85.39
271	6543	86.83
272	6546	88.26
273	6548	89.71
274	6551	91.18
275	6553	92.67
276	6555	94.18
277	6558	95.73
278	6560	97.26
279	6563	98.83
280	6565	100.4
281	6568	102.0
282	6570	103.7
283	6573	105.3
284	6575	107.0
285	6578	108.7
286	6580	110.4
287	6582	112.1
288	6585	113.9
289	6587	115.8
290	6590	117.5
291	6592	119.3
292	6594	121.2
293	6597	123.1
294	6600	125.0
295	6602	126.9
296	6604	128.8
297	6607	130.8
298	6610	132.8
299	6612	134.8
300	6615	136.9
301	6617	138.9
302	6620	141.0
303	6623	143.1
304	6626	145.3
305	6628	147.4
306	6631	149.6
307	6633	151.8
308	6636	154.1
309	6639	156.3
310	6641	158.7
311	6644	161.0
312	6647	163.3
313	6650	165.7
314	6652	168.1
315	6655	170.5
316	6658	173.0
317	6661	175.5
318	6663	178.0
319	6666	180.6
320	6669	183.1
321	6671	185.7
322	6674	188.3
323	6677	191.0
324	6680	193.7
325	6683	196.5
326	6686	199.2
327	6689	202.0
328	6691	204.8
329	6694	207.7
330	6697	210.5
331	6700	213.5
332	6703	216.4
333	6706	219.4
334	6709	222.4
335	6712	225.4
336	6715	228.5
337	6718	231.6
338	6721	234.7
339	6724	237.9
340	6727	241.1
341	6730	244.3
342	6733	247.6
343	6736	250.9
344	6739	254.2
345	6741	257.6
346	6745	261.0
347	6748	264.5
348	6751	268.0
349	6754	271.5
350	6757	275.0
351	6760	278.6
352	6763	282.2
353	6767	285.9
354	6770	289.6
355	6773	293.3
356	6776	297.1
357	6780	300.9
358	6783	304.8
359	6786	308.7
360	6789	312.6
361	6793	316.6
362	6796	320.6
363	6799	324.6
364	6803	328.7
365	6806	332.8
366	6809	337.0
367	6813	341.2
368	6816	345.4
369	6820	349.7
370	6822	354.0
371	6826	358.4
372	6829	362.8
373	6833	367.3
374	6836	371.8
375	6839	376.3
376	6843	380.9
377	6847	385.5
378	6850	390.2
379	6853	394.9
380	6857	399.6
381	6861	404.3
382	6865	409.1
383	6868	414.0
384	6872	418.8
385	6875	423.7
386	6879	428.7
387	6882	433.7
388	6886	438.8
389	6890	444.0
390	6893	449.2
391	6897	454.5
392	6901	459.8
393	6905	465.2
394	6908	470.6
395	6912	476.1
396	6915	481.7
397	6919	487.4
398	6923	493.0
399	6927	498.8
400	6931	504.6
401	6935	510.4
402	6939	516.3
403	6943	522.1
404	6947	527.6
405	6951	533.3
406	6955	539.2
407	6959	545.0
408	6963	551.0
409	6966	557.0
410	6970	564.0
411	6975	570.2
412	6979	576.5
413	6983	582.8
414	6987	589.3
415	6991	595.7
416	6995	602.2
417	6999	608.8
418	7003	615.4
419	7007	622.1
420	7012	628.8
421	7016	635.6
422	7021	642.5
423	7025	649.4
424	7029	656.3
425	7033	663.3
426	7037	670.4
427	7042	677.5
428	7046	684.7
429	7050	691.9
430	7054	699.2
431	7059	706.6
432	7066	718.9
433	7066	721.4
434	7073	728.9

can contain under the given conditions of pressure and temperature, as the steam considered is at the saturation point. To obtain the desired formula which will express the value of W in terms of the known quantities it is merely necessary to divide the members of Equation 2 by those of Equation 1, thus:

$$\frac{W}{1} = \frac{\frac{N p_1}{459.2 + t}\left(1.6494 + \frac{0.248\,t}{850 - t}\right)}{2.698192\, N \frac{p_2}{459.2 + t}}$$

which may be simplified by division to give,

$$W = \left(0.6113 + \frac{0.092\,t}{850 - t}\right)\frac{p_1}{p_2}$$

but (by Equation 3) $p_2 = p - p_1$ and by substituting this value of p_2 in the above equation there results:

$$W = \left(0.6113 + \frac{0.092\,t}{850 - t}\right)\frac{p_1}{p - p_1}\text{ ; or,}$$

$$W = \left(0.6113 + \frac{0.092\,t}{850 - t}\right)\frac{H}{2.036\,p - H} \text{ (Equation 4)}$$

where H represents the tension of saturated steam (or water vapor) at the temperature, t, in ins. of mercury.

In order to simplify matters, the first member of Equation 4 may be placed equal to K, thus:

$$W = \frac{K \times H}{2.036\,p - H} \ldots \text{(Equation 5)}$$

The values of K and H corresponding to all ordinary temperatures, are given in Table I. That is, Equation 5 is the desired simple formula which gives the maximum weight, W, (in pounds) of water vapor that one pound of pure air can contain when the total or observed absolute pressure in pounds per square inch is p, and the values of K and H correspond to the existing temperature, whatever its value may be. Table I. will also be found of much practical value in other connections by noting that H is simply the absolute pressure of saturated steam expressed in inches of mercury, the absolute pressure in lbs. per square inch being readily found for any desired temperature by dividing the values of H by 2.036; also K represents the ratio of the weight of 1 cu. ft. of saturated steam at any given temperature and corresponding pressure to 1 cu. ft. of pure air at the same pressure and temperature.

It is worthy of note, as demonstrated in the preceding discussion and as proved by numerous experiments, that the ratio just referred to is *not a constant* but has a different value for each temperature, consequently all of the tables heretofore published in text-books and hand-books which give the relative and total weights of air and water vapor and of the mixture, and which have been computed on the erroneous assumption that the ratio in question is a constant, are not to be relied on with any degree of accurracy, as the majority of the values furnished by such tables are far from being correct. Table II. given in this article is figured correctly by the use of the exact ratio for each temperature specified and should prove of much value in all moisture computations—some of its uses are demonstrated by the last two examples of the four which will now be given to illustrate a few of the important practical applications of Equation 5 and Tables I. and II.

SPECIFIC APPLICATIONS OF FORMULAS AND TABLES.

Example 1.—How low must the relative humidity be, when the atmospheric pressure is 14.7 lbs. per sq. in. and the outside temperature is 60°, in order that no moisture may be deposited in any part of a compressed air system carrying a constant gage pressure of 90 lbs. per sq. in.? The relative humidity of the atmosphere is, of course, the percentage of moisture which the air contains at any particular pressure and temperature as compared with the maximum amount which it can hold under the same conditions.

Solution.—In order to solve this problem it is merely necessary to use Equation 5 to determine the maximum amount of moisture trat 1 lb. of pure air can contain at 90 lbs. gage pressure (or 104.7 lbs. absolute pressure) and 60° temperature which may be easily done by aid of Table I., thus:

and to find the maximum weight of moisture

$$W \text{ (at 104.7 lbs.)} = \frac{K\,H}{2.036\,p - H} = \frac{0.6183 \times 0.5180}{2.036 \times 104.7 - 0.5180} = .001506 \text{ lb.;}$$

but in order that no moisture may be deposited that 1 lb. of air can contain at 60° temperature and 14.7 lbs. absolute pressure, thus,

$$W \text{ (at 14.7)} = \frac{K\,H}{2.036\,p - H} = \frac{0.6183 \times 0.5180}{2.036 \times 14.7 - 0.5180} = .01089 \text{ lb.;}$$

in the system, each pound of pure air must not contain over .001506 lb. of moisture, and therefore the relative humidity must not be above the following value:

$$\frac{.001506}{.01089} \times 100 = 13.83\% \ldots \text{(Answer)}$$

This example shows that, unless operating in an extremely dry climate, some moisture is sure to be deposited in the system and that this amount depends on the relative humidity of the atmosphere as well as on the outside temperature and the pressure carried in the main reservoirs.

contained by 1 lb. of pure air at 14.7 lbs. pressure and 70° temperature, by aid of Table I. and Equation 5, thus:

$$W = \frac{K\,H}{2.036\,p - H} = \frac{0.6196 \times 0.7332}{2.036 \times 14.7 - 0.7332} = 0.01556 \text{ lb.}$$

then the temperature to which the air must be cooled in order to cause the deposition of

TABLE II.—WEIGHTS, IN LBS., OF PURE DRY AIR, WATER VAPOR AND SATURATED MIXTURES OF AIR AND WATER VAPOR AT VARIOUS TEMPERATURES, UNDER NORMAL ATMOSPHERIC PRESSURE OF 29.921 INS. OF MERCURY OR 14.6963 LBS. PER SQ. IN. ALSO VALUES OF THE ELASTIC FORCE OR PRESSURE OF THE AIR AND VAPOR WHEN PRESENT IN SATURATED MIXTURES. (Copyright, 1908, by H. M.-Prevost Murphy.)

Temperatures in Fahrenheit Degrees.	Weight of One Cubic Foot of Pure Dry Air	Saturated Mixtures of Air and Water Vapor					
		Elastic Force of the Water Vapor or Saturated Steam in Inches of Mercury	Elastic Force of the Air alone when Saturated with Water Vapor in Ins. of Mercury	Weight of the Water Vapor in One Cu. Ft. of the Mixture, or Wt. of One Cu. Ft. of Saturated Steam	Weight of the Air in One Cubic Foot of the Mixture	Total Weight of One Cubic Foot of the Mixture	Weight of Water Vapor Mixed with One Pound of Pure Air
0	.086354	.0439	29.877	.000077	.086226	.086303	.000898
12	.084154	.0754	29.846	.000130	.083943	.084073	.001548
22	.082405	.1172	29.804	.000198	.082083	.082281	.002413
32	.080728	.1811	29.740	.000300	.080239	.080539	.003744
42	.079117	.2673	29.654	.000435	.078411	.078846	.005554
52	.077569	.3883	29.533	.000621	.076563	.077184	.008116
62	.076081	.5559	29.365	.000874	.074667	.075541	.011709
72	.074649	.7846	29.136	.001213	.072690	.073903	.016691
82	.073270	1.092	28.829	.001661	.070595	.072256	.023526
92	.071940	1.501	28.420	.002247	.068331	.070578	.032877
102	.070658	2.036	27.885	.002999	.065850	.068849	.045546
112	.069421	2.731	27.190	.003962	.063085	.067047	.062806
122	.068227	3.621	26.300	.005175	.059970	.065145	.086285
132	.067073	4.750	25.171	.006689	.056425	.063114	.118548
142	.065957	6.167	23.754	.008562	.052363	.060925	.163508
152	.064878	7.929	21.992	.010854	.047686	.058540	.227609
162	.063834	10.097	19.824	.013636	.042293	.055929	.322407
172	.062822	12.749	17.172	.016987	.036055	.053042	.471146
182	.061843	15.965	13.956	.021000	.028845	.049845	.728012
192	.060893	19.826	10.095	.025746	.020545	.046291	1.25319
202	.059972	24.442	5.479	.031354	.010982	.042336	2.85507
212	.059079	29.921	0.000	.037922	.000000	.037922	Infinite

Note.—Air is said to be saturated with water vapor when it contains the maximum amount possible at the existing temperature and pressure.

Example 2.—When compressing air into a reservoir carrying a constant gage pressure of 75 lbs., from a saturated atmosphere of 14.7 lbs. absolute pressure and a temperature of 70°, to what temperature must the air be cooled after compression in order to cause the deposition of moisture to commence?

Solution.—To answer this question, first find the maximum weight of moisture contained by 1 lb. of pure air at 14.7 lbs. pressure and 70° temperature, by aid of Table I. and Equation 5, thus:

$$W = \frac{K\,H}{2.036\,p - H} = \frac{0.6196 \times 0.7332}{2.036 \times 14.7 - 0.7332} = 0.01556 \text{ lb.}$$

then the temperature to which the air must be cooled in order to cause the deposition of moisture to begin may readily be found by placing this value of 0.01556 in Equation 5 together with the value of p equal to 75 + 14.7, thus:

$$0.01556 = \frac{K\,H}{2.036 \times 89.7 - H} = \frac{K\,H}{182.63 - H}$$

or $H = \frac{2.842}{0.01556 + K}$ and the temperature which

satisfies this equation is found by aid of Table I. to be approximately 129° F. (Answer.)

That is, in this case, unless the air be cooled to 129° before being drawn from the main reservoirs none of the moisture contained by it will be deposited in these reservoirs, so that the importance of reducing the temperature of the compressed air to that existing outside is clearly seen, for all of the excess moisture will be deposited while the air in this case is having its temperature reduced from 129° to 70° F.

Example 3.—When the outside temperature is 82° F., and the pressure of the atmosphere is 14.6963 lbs. per sq. in., the relative humidity being 100 per cent., in what time will one gallon of water be deposited in a main reservoir when the air is cooled to 82°, and the gage pressure is 100 lbs. per sq. in., when a compressor is supplying an average of 30 cu. ft. of the moist atmosphere per minute?

Solution.—To solve this problem it is merely necessary to find the difference between the maximum weight of moisture mixed with 1 lb. of pure air at the two pressures concerned, the temperature being 82° in both cases. For the atmospheric pressure of 14.6963 lbs. the desired weight may be computed by Equation 5 and Table I., or may be more easily found by aid of Table II., which gives the desired value in the eighth column as 0.023526 lb. For 10 lbs. gage pressure, the weight may be found by Equation 5 and Table I., thus:

$$W = \frac{A'H}{2.036\,p - H} = \frac{0.6211 \times 1.092}{2{,}036 \times 114.6963 - 1.092} = 0.002918 \text{ lb.}$$

and therefore the weight of moisture deposited by each pound of pure compressed air is 0.023526 — 0.002918 = 0.020608 lb. Now Table II., column 6, shows that each cu. ft. of the moist atmosphere contains 0.070595 lb. of pure air, therefore the number of cu. ft. that must be delivered to cause 1 lb. of water to be deposited is:

$$\frac{1}{0.070595} \times \frac{1}{0.020608} = 687.37 \text{ cu. ft.}$$

and one gallon of water weighs 8.32 lbs. (approximately) at 82° F., therefore 8.32 × 687.37 = 5,719 cu. ft. of the moist atmosphere must be delivered to cause one gallon of water to be deposited, and the time required with the 30-cu. ft. compressor will be:

$$\frac{5{,}719}{30} = 191 \text{ min. (approx.)} = 3 \text{ hrs., } 11 \text{ min.}$$

(Answer.)

This example shows clearly that a large amount of moisture may be deposited in a very short time, under certain conditions, and thus emphasizes the importance of frequently draining the main reservoirs, which if not properly attended to may not only have their air storage capacity greatly depleted by the presence of the water, but may in time become so full of it that there will be no room left for the deposition of additional moisture and consequently the radiating system will be rendered of no value.

Example 4.—With the same system and under the same conditions as those stated in Example 3, what is the loss in volumetric efficiency of the plant when the excess moisture is properly trapped in the main reservoirs?

Solution.—To solve this problem it is merely necessary to proceed as follows: Table II. shows that, before compression, each pound of pure air is mixed with 0.23526 lb. of water vapor and that the weight of 1 cu. ft. of the mixture is 0.072256 lb., consequently the volume of the 1 lb. of air and 0.023526 lb. of vapor is

$$\frac{1.023526}{0.072256} = 14.165 \text{ cu. ft.}$$

Now for 100 lbs. gage pressure and 82° temperature, it was shown in Example 3 that 1 lb. of pure air can hold only 0.002918 lb. of water vapor in suspension, each pound of air having deposited 0.020608 lb. of water in the main reservoir. Also Table II. shows that the weight of 1 cu. ft. of pure water vapor at 82°, and at the corresponding tension of 1.092 ins. of mercury, is 0.001661 lb., consequently by Dalton's law the volume of the mixture consisting of 1 lb. of pure air and 0.002918 lb. of saturated water vapor (or steam), at 100 lbs. gage pressure is the same as that of the saturated steam alone under the conditions just mentioned, that is, the volume of the mixture is:

$$\frac{0.002918}{0.001661} = 1.757 \text{ cu. ft.}$$

(This value may easily be checked by finding the pressure in inches of mercury of the 1 lb. of pure air when compressed into this volume, which when added to 1.092 will give the total pressure of the mixture, namely, the absolute pressure in inches of mercury corresponding to 100 lbs. gage pressure.)

Finally (by Marriotte's or Boyle's law), the volume of these 1.757 cu. ft. of mixed gas at 114.6963 lbs. absolute pressure when expanded to atmospheric pressure will be,

$$\frac{114.6963}{14.6963} \times 1.757 = 13.712 \text{ cu. ft.;}$$

consequently the decrease of volume, that is, the loss of volumetric efficiency is,

$$14.165 - 13.712 = 0.453 \text{ cu. ft., or } \frac{0.453}{14.165} \times 100 = 3.2\%. \text{ (Answer.)}$$

This example shows clearly that, particularly in warm, moist climates, there is a very appreciable loss in the efficiency of compressors, due to the condensation of water vapor. Of course this loss is unavoidable in railway work, and is far preferable to allowing the moisture to pass into the working parts of the system, but in stationary work where reheaters are used, this cause of decreased efficiency may be obviated, and this problem should be of particular interest in this connection, as losses due to this cause have not been carefully considered heretofore and yet may clearly play a very important part in the economical operation of compressed air plants.

THE DEHYDRATION OF AIR

By Joseph H. Hart.

The problem of the dehydration of the ordinary atmosphere for its more efficient utilization in commercial or engineering developments is not one that has appealed, as yet, to the average engineer nor one with which he is at all familiar. The small proportion of water vapor present in the air, although with its deleterious effect in many industries still recognized, has generally been considered of too small account for active consideration in regard to its removal. To-day, however, it is generally recognized that it can be efficiently removed by a number of different processes, which is a distinct step in advance in many industries, and has increased the efficiency of their processes enormously.

In order to realize the extent to which this development has progressed and its possibilities in future installations, we will cite the case of blast-furnace operation for the manufacture of iron. The application of dry-air blast obtained by means of refrigerating machinery has been successfully and economically employed in the Pittsburg district. Isabella furnace at Etna, Pa., produced 350 tons of iron with 2,147 pounds of coke per ton of output, and consumed approximately 40,000 cubic feet of air per minute. The refrigerating plant installed consisted of two ammonia compressors of a nominal capacity of 225 tons of ice-melting effect each. One only of these compressors is generally operated, and the other is held in reserve to help out on especially humid days. The air was cooled from 80 degrees to about 28 degrees F., and the moisture content was lowered from 5.66 grains per cubic foot, as existing in a special test, to 1.75 grains. The air handled after the blowing engines were slowed down, on account of increased density and removal of the moisture, was 34,000 cubic feet per minute. About ten tons of water was collected from the air per day, and the output was increased to 450 tons of iron, with a coke consumption of 1,729 pounds per ton of output. The blowers were slowed down from 114 to 96 revolutions per minute, the air was reduced in amount as stated, and the indicated horse-power of the blowers from 2,700 to 2,013; thus showing a saving of 687 horse-power in operating the blowing engine. As the refrigerating machinery would only require about 530 horse-power when operated at its maximum capacity, the saving in this factor alone was considerable. In addition, the quality of the iron is improved and can be made very constant in character. The ore and fuel were of uniform condition formerly, but the humidity of the air was very variable. It may vary in one day from 20 per cent. to 100 relative humidity, and this may mean a variation of 300 per cent. total in the complete water content for each grain of water vapour present per cubic foot of air. The moisture content which passed through the furnace was approximately 40 gallons of water per hour, and at times this was increased to over 300 gallons.

This synopsis of exact conditions as existing

in one special development will show the great importance and possible efficiency of the process in many other applications. The fact that the air is cooled from 80 degrees F to 28 degrees F. during this process, and that this remarkable efficiency can be shown, is a matter for much further surprise and speculation.

Dehydrated air is absolutely necessary in the cotton industry, in tobacco warehouses and in tobacco manufacture in general, in very many of the great storage developments, and, as is shown above, its practical application in the metallurigcal industries results in a remarkable increase in efficiency. Further, to-day air is used for producing cold water by the absorption of vapour from water immediately in contact with it, with the consequent cooling of the water due to the absorption of the latent heat of evaporization required for this operation. Cooling towers, so called, are extremely common in many refrigeration installations, since cold water is absolutely necessary for the operation of the condenser. In fact, wherever condensers operate, if of the open-type variety, they are much increased in efficiency by satisfactory dehydration of the air and the consequent further cooling of the water. A remarkable condition holds in regard to this special development, namely, that warm, dry air has a much greater cooling effect, due to its absorptive power, than cold, moist air used under similar conditions.

The moisture content of the air is a very variable quantity. It varies with locality and with its contiguity to a large body of water. Temperature variations affect its value very greatly, and it is very variable with weather conditions generally. The relative humidity is defined as the ratio of the quantity of moisture that the air holds per given unit at a given temperature to the quantity that it could hold at that temperature without condensation. The water content of atmospheric air will vary 300 per cent. between limitations as represented by February and June conditions without much variation in relative humidity.

This moisture can be removed by any of a large number of chemical agents known as dehydrating compounds. Sulphuric acid and calcium chloride are the chief and most active of these, and formerly air was dried very satisfactorily by being blown through drums filled with calcium chloride or allowed to bubble through tanks containing sulphuric acid. For some reason or other, probably on account of the difficulty of handling the chemical, if calcium chloride, and the deteriorating effect of sulphuric acid on the retaining vessel and the machinery in general, this development has not been general in its utilization. In special applications, such as physical and chemical laboratories, where dry air is often a necessity, in the production of liquid air as a commercial process, and in a number of other minor developments, these processes have been developed and are fairly efficient.

Undoubtedly the special development in the blast furnace, where dehydration is accomplished through refrigeration, owes a very great degree of its efficiency to the increased density of the air, as well as to the removal of the moisture content. Air kept at constant pressure and cooled decreases in density in direct proportion to its absolute temperature fall, and it can be readily assumed that this development in iron-furnace operation will be much extended, with further increase in efficiency, if further cooling can be accomplished without undue loss in the efficiency of that process. In this development it is undoubtedly the cumulative effect of these two effects which results in the remarkable increase in efficiency as shown.

Air, as a general dehydrating agent, will not come into general use in every development, since it possesses a strong competitor in the utilization of superheated exhaust steam for the performance of this duty. Many woolen and textile mills dry their fabric by this application, with very satisfactory results. It is more efficient and more readily available than dry air, on account of its higher temperature and large water absorptive power, since the total moisture content increases rapidly with rise in temperature, and the tendency of all such materials is to become saturated on contact with water.

While undoubtedly blast furnaces could probably remove the water content of the air by means of any of the dehydrating agents, and do it even more efficiently, when the cost of refrigerating machinery is considered, this application is by no means limited in its further development. A number of continuous dehydrating machines utilizing sulphuric acid or calcium chloride have been developed to-day, notably that used in the production of ice by

means of the vacuum process, whereby water is made to freeze itself by the rapid evaporation in a vacuum from its surface, with the further absorption by sulphuric acid of the vapour as fast as produced. In this plant the sulphuric acid is carried in a closed cycle continuously in a very efficient process, and the further application of this development for the removal of the moisture from the blast in iron-furnace operation would be very efficient and could be accomplished with minimum first cost in installation of plant. The real application of mechanical refrigeration in this development is undoubtedly the compression of the air with increased efficiency through the increase in density both on account of the removal of water vapour and on account of lowering of initial temperature of compression. Again, the compression itself is accomplished much more effectively with high air density and low initial temperature, since, if accomplished adiabatically, the final exhaust temperature is much diminished, and the mean operating pressure diminished with a further partial elimination of the more inefficient portion of the stroke. That this development will extend to the preparation of air for compression before its production by means of the air compressor is a foregone conclusion, and the efficiency of the process can scarcely be conjectured, since many of the data for such calculation are not at hand. However, it must be born in mind that this problem—namely, that of variation of density and temperature of air—is always present with dehydration, however accomplished. The extent to which the moisture present is objectionable can be readily seen from the foregone example, and undoubtedly many future possibilities are offered for this development. In all vacuum stills where the distillation is accomplished at temperatures lower than those existing under normal atmospheric pressure, this development presents possibilities. In sugar refineries, where the syrup is boiled down at diminished temperature by a maintenance of a vacuum; in condensed milk factories, in oil refineries, and, in fact, wherever distillation occurs under these abnormal conditions, the same result—that of dehydration of this material—can be accomplished readily by blowing dehydrated air through the mixture. Of course, sulphuric acid can be substituted for the absorption of the moisture whenever practicable; but under the example cited its ultimate removal is almost impossible, and it often has a very injurious effect on the finished product.

In a general way, it can be stated that the problem of air dehydration possesses manifold applications. The utilization of refrigeration for the actual dehydration in a number of specific developments will have the sole result ultimately of bringing this problem to the attention of the average engineer, since in all probability the results obtained, while accomplished with remarkable efficiency by mechanical refrigeration, can undoubtedly be successfully attained by much more efficient processes of dehydration.—*Condensed from Cassier's.*

EFFECT OF AIR IN THE CLARIFICATION OF CANE SUGAR

Throughout the substance of the sugar cane there exists quite a large amount of air and other gases, produced in part by the activities of the plant and in part introduced through insect punctures and other injuries. Also, when a normal feed of cane passes between the mill rolls there is entangled a vast quantity of air intimately mixed with the fibre when the bagasse expands like a squeezed sponge as it is relieved from the pressure. Even when maceration water is plentifully used upon this half-dry bagasse, and applied as quickly as possible, not nearly all this air is driven out, as can be plainly shown by squeezing a handful of it under water.

Now, when this partly air-filled, wet bagasse reaches another mill the air and liquid are together subjected to the enormous pressure of the hydraulics (a pressure often still greater with a rigid mill) with the result that a very large part of the air is actually dissolved in the juice by the pressure, precisely as soda water is charged with gas; and juice being more viscous it requires a much longer time for the air to escape on standing than for the gas to separate from carbonated water.

Before an accurate spindle reading can be made, mill juice must stand for some time for the froth to rise, but if, after all this froth has separated, a portion of the underlying and foam-free juice is drawn into a narrow test tube and the air above it is exhausted by suction or otherwise, the reduced pressure will immediately cause to escape to the surface a

second cloud of minute air bubbles; and if heat is then applied while a slight vacuum is still maintained, all the remaining air is removed.

Cane juice as it comes from the mill always contains a large amount of air both as air bubbles (froth) and in actual solution; and the length of time between the escape of the juice from the mill and its entry to the juice heater, clarifier, or other defecating apparatus is too short to allow any measurable amount of this entrapped gas to escape. This slowly escaping air is the sole cause of the "capa" or blanket that forms on the surface of the open clarifier, and would otherwise be precipitated to the bottom as a heavy mud.

Each minute bubble of air attaches itself as it forms to a particle of scum, and these bubbles, expanding as the heat increases, bring the impurities to the top with them. Many houses using heaters and high temperatures for the juices with open vessels for settling, are sometimes compelled to boil the juice in these vessels to eliminate the air and secure a separation of the impurities. If the air and gases should be quickly and completely removed between the heater and the open settling vessels the quality and effectiveness of the defecation would be greatly improved.

If passed through a juice heater the immediate effect of higher temperature is to release a large part of the air, but if kept under any considerable pressure all of it cannot escape, or only slowly; and in the modern closed defecation under pressure this slow release of gases subsequent to passage through a superheater causes trouble, for, in a pressure separator, the evolution of gas takes place throughout the whole body of the liquor and the rising bubbles interfere by their upward motion with the downward travel of the scum or cachaza, and slow the subsiding process seriously; also, at the bottom of any tank used for seperation of the mud, the air will be trapped, collecting in large bulk until some momentary disturbance will cause it to break loose and carry with it masses of solid impurities into the separated juice.

One is led to the conclusion that removal of the air must be effected by some form of apparatus which will expose the hot air-charged juice to reduced pressure in an expansion chamber and at the same time spray it in a manner to insure immediate separation of the gases.

This should be done in an apparatus virtually consisting of a shell of wrought iron receiving the hot juice within it through a perforated pipe or sprayer, combined with a surface condenser enclosed in the expansion chamber, formed of tubes through which cold juice circulates on its way to the heater, and the expansion chamber having connections with a vacuum condenser for taking away the air and gases.

The water from condensation of the steam can be readily trapped off, representing so much evaporation, and after passing through such an apparatus the juice, entirely air-free, will deposit its impurities quickly and completely if the liming has been properly attended to.—*Louisiana Planter.*

PRACTICAL PNEUMATIC MILKING

As we have to do with everything pneumatic it comes entirely within our province to describe the interesting apparatus shown in the accompanying half-tone. Instead of being a compressed air apparatus this is operated by vacuum, produced and maintained by a small air pump which may be driven by an electric motor or otherwise, as most convenient.

The system of milking embodied in this apparatus is far and entirely beyond the experimental stage and is in established and extensive use, giving complete satisfaction whereever installed, besides showing substantial savings in the ultimate cost of operations.

The partial vacuum used with the milking machines is about one-half atmosphere. The pump used is of the vertical, single-acting type, placed in any convenient location, and a line of 1¼ or 1½-inch pipe is led along by the stalls, with branches suitably located for connecting between each pair. A vacuum reservoir tank, a safety valve and two vacuum gages are included in the installation.

The milking machine, as it may be called, consists of a strong, heavily tinned, steel pail Fig. 1, weighing about 12 pounds and holding about 55 pounds of milk. The pail is smaller at the top than at the bottom, with a metal cover fitting loosely, but resting on a soft rubber gasket which makes an air-tight joint. A nipple projecting from the cover connects the pail through a suitable hose with a branch

cock in the piping system. The cover contains an automatic pulsating mechanism, and attached to it are two lever handle cocks, each of which is connected by a rubber tube 3½ feet long to a small metal connection with four outlets, from each of which a short rubber tube leads to a teat cup provided with a rubber mouthpiece to fit around the base of the teat. When these are slipped on over the teats they are held in place by the suction until removed by the operator. These teat cups, with their rubber mouthpieces, are made in several different sizes to fit different sized teats, and the chief skill or judgment required of the operator is choosing the proper sizes. The pulsator, mounted on the cover, imitates the sucking of the calf, the teat cups first connecting with the vacuum maintained in the pail, thus drawing the milk from the teat; and next breaking the vacuum and allowing a fresh flow of milk into the teat. The vacuum is again created in the cups, an additional portion of milk goes into the pail, and so on continually, until the milk is all drawn.

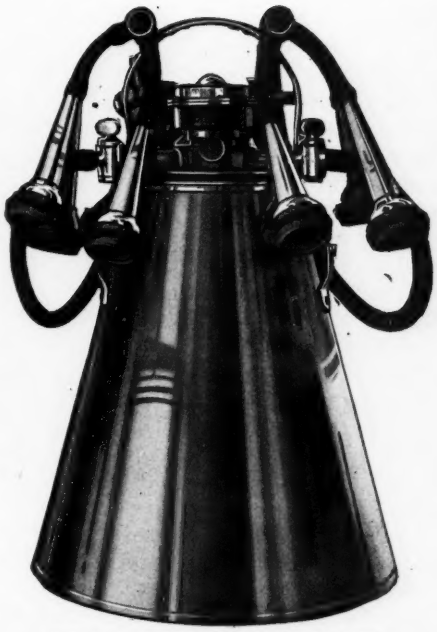


FIG. I. VACUUM MILKING APPARATUS.

Each milk pail is connected to the vacuum mains and also to two cows, as shown in Fig. 2. The milk pail, as was said, holds about five gallons, is air tight and *the milk is not exposed to the air* until it goes to the strainers. An operator usually attends to four cows at a time, and the work is done in about the same time that the hand operation would require for one cow, this time varying of course as the cow milks hard or easy. The cows do not seem to be in any way injuriously affected by the use of the machine; in fact it is said that after a cow has been milked by the machine for a few weeks she will most strenuously resent the hand process.

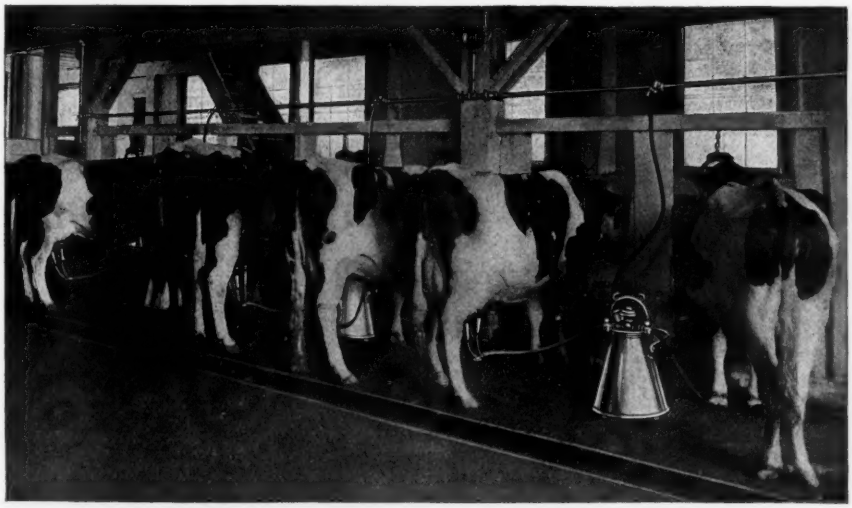


FIG. II. COW-MILKING MACHINES IN USE IN A NEW YORK STATE DAIRY.

The man in charge cleans off the cow's teats and after attaching the milk pail to the main the cups are slipped over the teats and the milking begins. Passing from cow to cow he thus starts the apparatus at work, and then simply keeps watch to see when the milk stops flowing, which is shown in a glass tube on the milk line, when he removes the cups and goes to another cow. Sometimes during the fly season the cow will dislodge the cups, in which case the man in charge has to replace them. This is about all he has to do in the matter, so far as the milking is concerned.

Fig. 2 is from an installation in the New York dairy region showing the milkers in operation. The second and third cows from the right in this picture have been machine milked for over five years. The second one is now giving a little over 50 pounds of milk per day.

These milkers with all appurtenances are built by D. H. Burrell & Co., Little Falls, N. Y. A typical outfit for a certain dairy cost the user all installed, but without the electric motor, less than $275. The cost of operating it, with current at 6 cents per kilowatt-hour, is about $6 a month, and the plant will take the place of two men on a dairy farm caring for 30 to 50 cows.

JOINTS AND FITTINGS FOR HIGH PRESSURE AIR

By H. V. Haight.*

In a pneumatic haulage plant where air pressures of 700 to 1,200 pounds per square inch are employed the detail work of the design is largely a problem of joints, valves and pipe fittings. Only ordinary care and good judgment are needed in the design of these details; it is the common experience in coal mines that with a pneumatic haulage system which has been carefully designed, constructed and erected, there is actually less trouble from leakage with air at 1,000 pounds pressure than with ordinary systems using air at 100 pounds pressure. A plant consisting of an air compressor, an extensive system of piping with valves and fittings, and several locomotives can be made practically bottle tight with air at 1,000 pounds pressure without undue trouble or expense. This being the case, it would appear that with reasonable care a compressed-air system for 100 pounds pressure also can be made practically bottle tight.

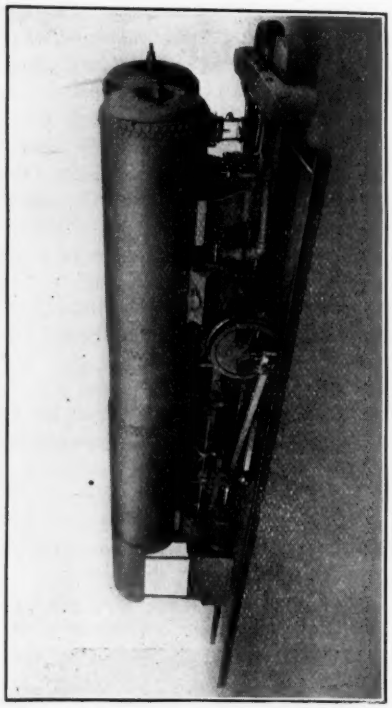


FIG. II. A PNEUMATIC LOCOMOTIVE STORING AIR AT 800 POUNDS PRESSURE.

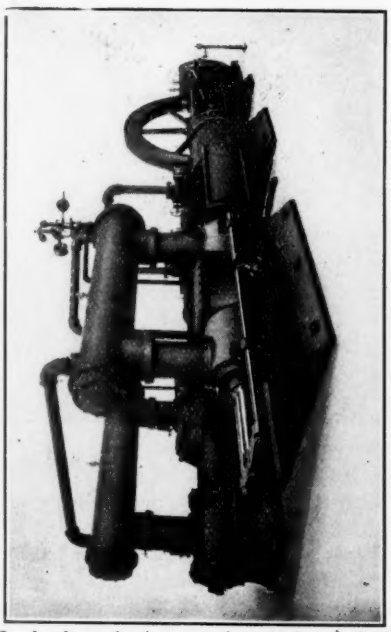


FIG. I. A FOUR-STAGE AIR COMPRESSOR—TERMINAL PRESSURE 1000 POUNDS.

It is hoped that a description of fittings which have been successfully used for high-

*Chief Engineer, Canadian Rand Company.

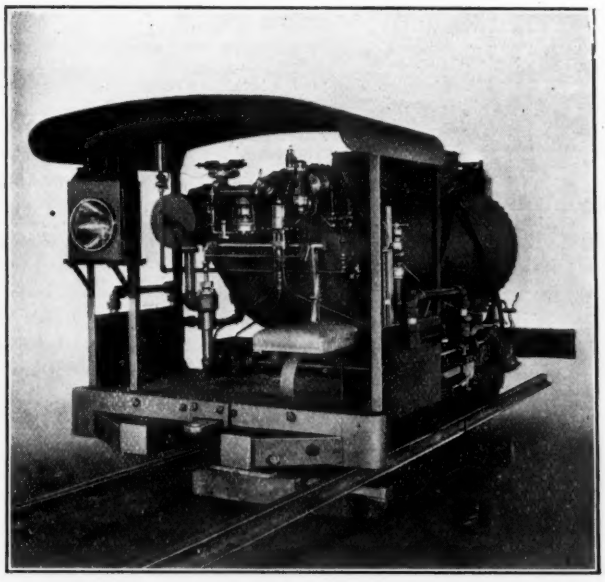


FIG. III. ENGINEER'S END SINGLE TANK LOCOMOTIVE.

pressure air will be of assistance to those who wish to improve existing piping systems, or to install new systems; whether for ordinary or for high air pressures.

The fittings which I purpose to describe are most of them used in connection with Rand Company for coal mines in western Canada. A pneumatic haulage plant consists essentially of an air compressor, a pipe line, used for both storage and distribution, and one or more locomotives.

THE COMPRESSOR PLANT.

For coal mines this usually consists of a duplex steam-driven compressor with its boil-

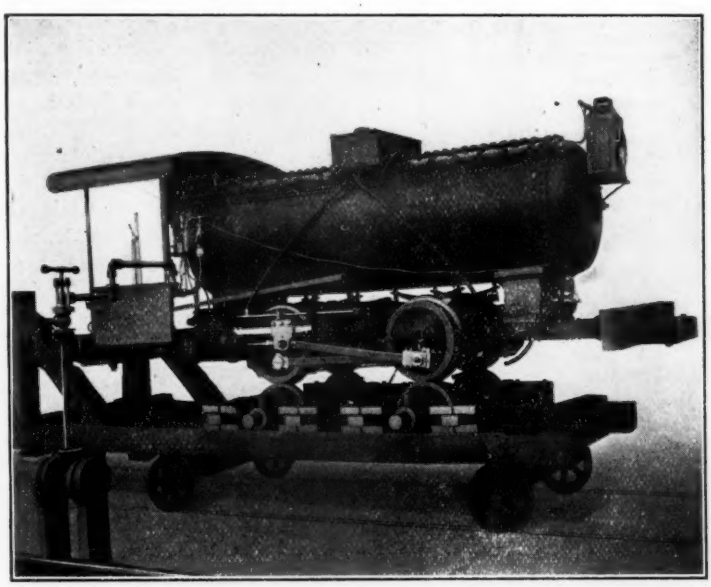


FIG. IV. SIDE VIEW OF LOCOMOTIVE UNDER TEST.

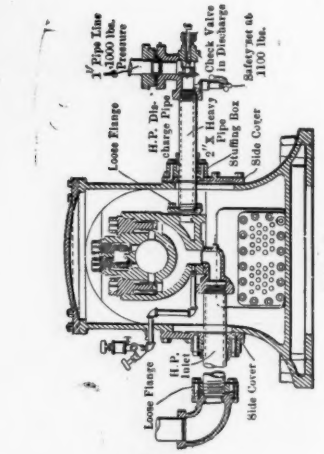


FIG. 6

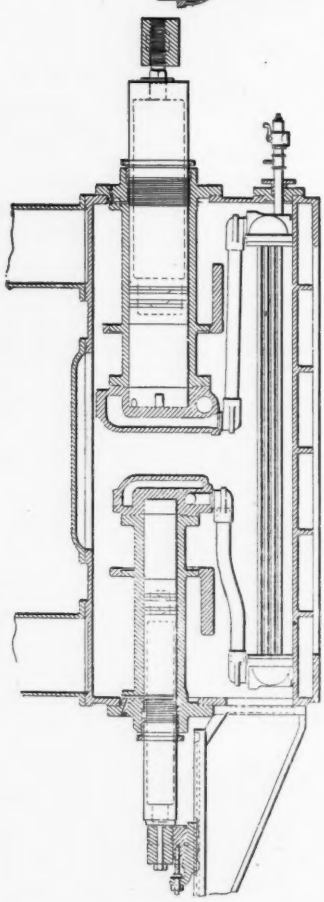


FIG. 5 TANKS CONTAINING THIRD- AND FOURTH-STAGE CYLINDERS

ers and auxiliaries. The air end is four-stage; the terminal pressure is about 1,000 pounds per square inch and the intermediate pressures are about 25, 100 and 375 pounds, respectively. The steam cylinders have usually balanced Meyer valves; although the Pacific Coal Company, near Banff, has a compressor with compound Corliss steam cylinders. Fig. I shows a compressor having duplex Meyer steam cylinders and four-stage air cylinders.

THE PIPE LINE.

The compressed air is delivered into the pipe line which serves both for storage and for distribution. Pipe is cheaper than tanks, even if it is used only for storage, and when large pipe can be used for both storage and distribution it is evidently very much cheaper than separate storage tanks and small distributing pipe. At suitable places along the pipe line are located charging stations for filling the tanks on the locomotives. When the tank is connected to the pipe line and the valve is opened the pressure is equalized at about 800 pounds. With 1,000 pounds pressure in the storage line, 150 pounds pressure remaining in the locomotive tanks and with a capacity ratio of pipe line to tank of 4 to 1 the pressure should equalize at 830 pounds.

THE LOCOMOTIVES.

Pneumatic locomotives are shown in Figs. 2, 3 and 4. The locomotive carries either one or two high-pressure tanks in which air is stored at 800 pounds pressure. From the storage tanks it passes through a series of stop and reducing valves to the auxiliary reservoir where the pressure is maintained at about 150 pounds. Thence the air is admitted by the throttle to the cylinders.

COMPRESSOR JOINTS.

The high-pressure fittings and joints of the air compressor are nearly all used in connection with the tank containing the three and four-stage cylinders. A longitudinal section of this tank is shown in Fig. 5. This shows one of the first machines built; on later machines the pipes connecting the intercooler to the heads have been placed outside the tank for convenience of access. Fig. 6 shows a cross section of the tank on one of the later machines. Referring first to the plunger packing, Fig. 5 shows plungers packed with both piston rings and stuffing boxes; on the later machines the piston rings were omitted as unnecessary. A section of the fourth-stage stuffing box and details of the packing ring and oiler ring, or "lantern," are shown in Figs. 7 and 8.

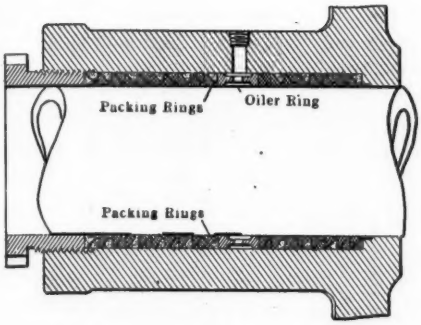


FIG. VII. FIVE-INCH PLUNGER PACKING.

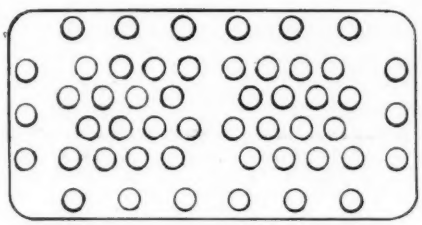
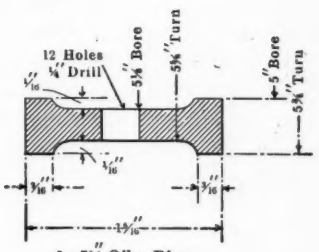
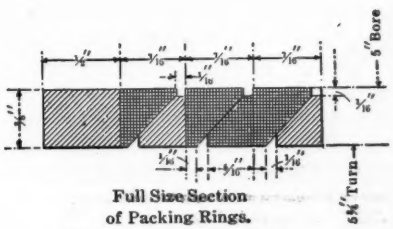


FIG. IX. REVISED LAYOUT OF STUD HOLES IN A TUBE PLATE.





Note:- Every Alternate Ring on Outside of Red Brass

17 - 5 Inside Rings } 2 lbs. Genuine Bbt.
8 - 5 Outside Rings }
9 - 5 Outside Rings - Red Brass 1 lb. Lead

FIG. VIII. DETAILS OF OILER AND PACKING RINGS.

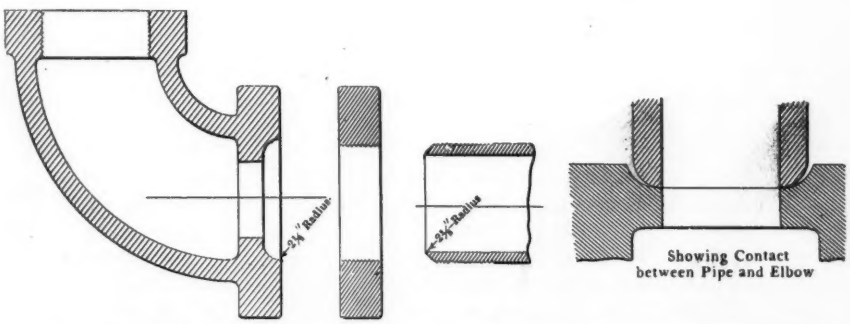


FIG. X. DETAILS OF AN ELBOW AND COMPANION FLANGE OF A BALL AND SOCKET JOINT

It will be seen that the inner rings are all of soft babbitt (two pounds of genuine babbitt to one pound of lead) while half of the outer rings are of babbitt and the rest of red brass. If the outer rings were all of babbitt they would wedge against the outer wall so tightly that it would be very difficult to remove the packing. On the first machine the plungers were simply turned smooth, but the erecting engineer reported that the packing wore away quite rapidly until the plungers had begun to wear smooth. On later machines the plungers were ground and gave no trouble. This packing has given excellent results on large plungers. The position of the oiler ring may perhaps be criticized and it would probably be better to place it nearer the stuffer. Plastic packing was also tried with these plungers. Three grades of commercial plastic packing, each consisting of grains of soft alloy packed in "sausages," were tried on a small machine with a 2⅜-inch plunger. Two of the packings would not hold a pressure of 800 pounds; the third kind proved satisfactory

on small plungers. This space for packing was the same as for metallic rings; namely, ⅜-inch all around the plunger.

This same kind of plastic packing was afterward used on large five-inch and nine-inch plungers, but the space for the packing was made ¾ inch. In this case it did not give altogether satisfactory results; there was liable to be a little more packing on one side of the plunger than on the other, and the stuffer could not be screwed up hard enough to pack it all around. The use of a few rings of soft packing in conjunction with the plastic metallic packing might distribute the pressure evenly and overcome the difficulty; or, it may be, if only ⅜ or ½-inch space were allowed for the packing the stuffer could be screwed up tight enough to distribute the packing equally around the plunger. On the whole, however, babbitt rings have been more satisfactory for large plungers.

The intercooler shown below the cylinders carries a working pressure of 375 pounds per square inch. It consists of copper tubes ¾ inch outside diameter and about 1-16 inch thick, expanded into steel-tube plates ⅞ inch thick. These tube plates are secured by studs to headers. Referring to the cross section, Fig. 6, it will be seen that at each corner of the plate there is a stud which comes almost exactly in the corner. Professor Sweet's rule in regard to placing studs on a rectangular plate such as this is: "The studs should not be placed right in the corners." As a matter of fact, with the arrangement shown the corners bent down, causing leakage. The layout of studs was changed to that shown in detail, Fig. 9, which gave no farther trouble. The gasket between the tube plate and header is made of copper wire about 3-16 inch in diameter. A good grade of sheet packing might, however, serve the purpose all right.

A rather peculiar difficulty was experienced with the tubes of one of these intercoolers. In this case the tubes were made of brass, and although they stood the water test at the shops all right, it was reported when the machine was started that some of them were cracked. The matter was taken up with the manufacturers of the tubes, and their explanation was that the tubes were not annealed, that we did not specify annealed tubes, or state what they were to be used for, and that

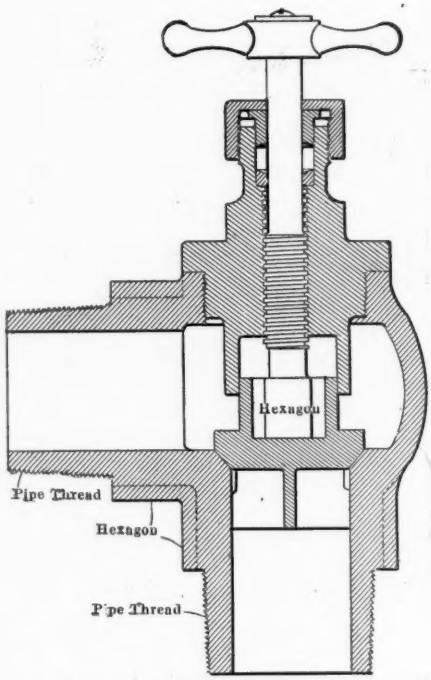


FIG. XI. A HIGH-PRESSURE CHECK AND STOP VALVE.

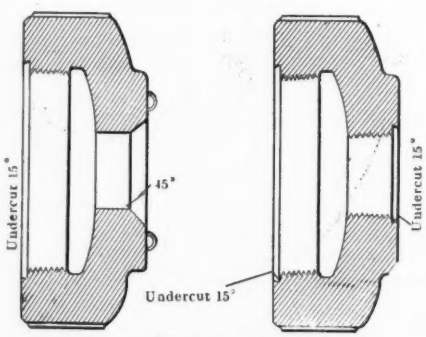


FIG. XII. TWO STYLES OF REDUCING COUPLINGS.

they had sent us unannealed tubes. They stated that these were liable to crack in transit, or even in the store-room. We could not imagine any purpose for which such tubes would be suitable, and concluded that in future it would be safest to use copper tubes.

COMPRESSOR FITTINGS.

The fittings shown in Fig. 6 may next be described. A very convenient fitting is the ball and socket joint with loose flange, shown where the high-pressure inlet is attached to

the elbow outside the tank, and also where the high-pressure discharge is attached to the head. A detail of the elbow and companion flange is shown in Fig. 10. The thread is not subjected to air pressure, so it is made straight and the flange screwed on by hand. As the joint is against the end of the pipe, there is only one joint instead of two or three as in the case of an ordinary companion flange. The ball and socket feature makes the joint tight even if the parts are not in line. The flange being loose can be readily removed when it is necessary to take that off the side cover of the tank. It is this feature in particular which makes this joint so convenient where it is necessary to slip anything over the end of the pipe before the joint is made. Extra heavy pipe was used in making these joints in order to have sufficient thickness left after threading. Seamless tubing would probably be better than lap-welded pipe, as there would be no seam coming right in the joint. However, extra heavy pipe did not give any particular trouble on this account. It will be noted that the radius at the end of the pipe is made slightly less than the radius of the corresponding socket. This gives in effect a line contact at the smallest diameter of the joint so that it is not necessary to screw up the bolts very tight in order to develop sufficient pressure between the opposing surfaces to hold the air pressure. It may be asked why the companion flange to the check valve was not made in the same way. The reason is that the latter is a field joint and it would not be convenient to have the end of the pipe specially threaded and faced.

It will be noted that the stuffing boxes for the pipes are made separate from the side covers for the tank. On the first machine the stuffing boxes were cast on the covers, but it was found that after the cylinders were assembled in the tank the pipes did not always come right in line with the stuffing boxes. The covers are now cast plain, and are drilled for the pipes after the other parts are assembled and the pipes located.

The style of check valve shown in the discharge pipe is used with slight modifications for either a stop or a check valve on compressor, pipe line and locomotive. A section of one of these valves is shown in Fig. 11, and it will be seen that it is the same style as an ordinary locomotive check valve. The stem

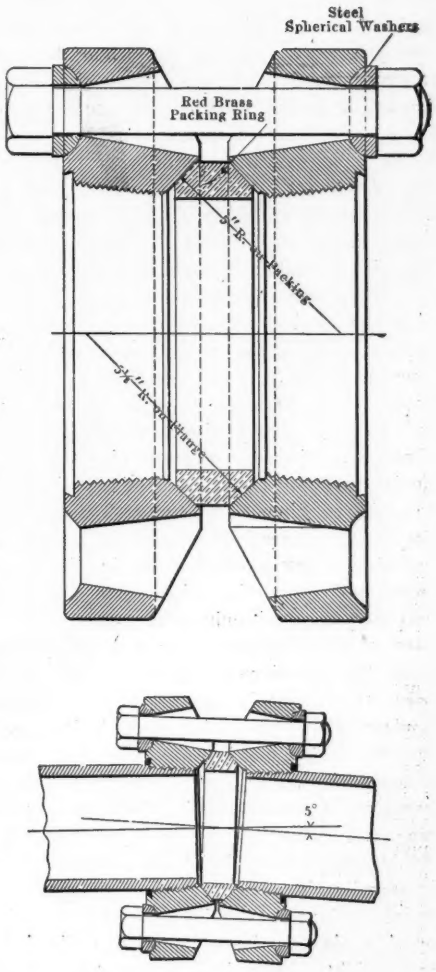


FIG. XIII. A FLANGE UNION FOR 1000 POUNDS AIR PRESSURE.

may be used to turn the disk and thus grind out any dirt which may have lodged on the seat, or the valve may be locked shut. When used as a stop valve the hexagon on the stem is turned off round. The stem of a stop valve of this style gave way under pressure, shortening and increasing in diameter and changing the pitch of the thread. The stem that failed was made of yellow brass bar. It was replaced by a cast-bronze stem which stood all right. The stress in the stem where it failed figures out about 4,000 pounds per square inch with 800 pounds pressure. The bodies are made of red brass and the stress in the body at *T*, assuming the shape

to be spherical, figures out 2,000 pounds per square inch. Neither of the above stresses were, however, figured out when the valves were designed; they were simply proportioned according to the judgment of the designer.

PIPE LINE FITTINGS.

As explained above, quite large pipe is used in order to act as storage; the sizes most commonly employed being 4, 5, or 6-inch. Very much smaller pipe would do simply to transmit the air, so that it is customary to use 1½ to 3-inch pipe from the compressor to a point outside the engine room where the large pipe begins. Small pipe is also used where it is necessary to pass under and over the railroad track, or at any place where it would be difficult to get around with large pipe. Fig. 12 shows two different styles of pipe caps or reducing couplings for connecting 6-inch pipe to 2½-inch pipe. The companion flange for the flange connection is made the same as the one shown on the check valve in Fig. 6. For this small connecting pipe extra heavy pipe and steel ammonia elbows are used.

As there is usually at least a mile of large pipe, the question of cost becomes an important one; while extra heavy pipe would doubtless be quite satisfactory, it is stronger than necessary, and is quite expensive. Standard pipe is hardly strong enough. There is, however, a grade of pipe between standard pipe and extra heavy known as full-weight, or line pipe. What is known as standard pipe is actually about 10 per cent. lighter than the weights given in standard lists. Full weight, or line pipe, is, however, of the dimensions and weights shown in lists for standard pipe. (This is the explanation a pipe salesman gave me.) This does for storage pipe very well, although there have been a couple of instances where some lengths of this pipe split in service. In one case a piece of 5-inch pipe carrying 900 pounds pressure burst in cold weather without apparent cause. In another case a car ran into a 4-inch pipe carrying 850 pounds. It broke where it was struck and also at the end, five lengths beyond where it was struck. The results of the split were not, however, very serious. The H. K. Porter Company got a special pipe for this purpose made from selected skelp and very carefully worked. This seems to give most satisfactory results.

The couplings used are of a special type made extra heavy with long threads and recessed for calking with lead. If the pipe is screwed up properly there are, however, no joints which it is necessary to calk with lead. When screwing up 4-inch pipe, for instance, there will be a gang of about seven men, six of them with three pairs of heavy pipe tongs screwing in the pipe and one man at the joint. The pipe which is already screwed up is held from turning by a clamp.

It is not found necessary to make any special provision for expansion in these pipe lines.

For flange unions in the pipe line the ball-joint flange union shown in Fig. 13 is a very handy fitting. As it permits a movement of 5 degrees in any direction, it may be used wherever there is a small change in the direction of the pipe line. Where a greater change in direction is required the pipe is bent; if the bend is not exactly correct the difference may be conveniently made up by one of these flange unions. A style of high-pressure flange union very commonly used has a babbitt packing ring. This is liable to leak after the pressure has been pumped up and lowered again, and have to be tightened occasionally. The pipes must also be exactly in line, or they will leak. With the flange unions shown in Fig. 13 these difficulties do not exist. The erecting men like them very much on account of their convenience when laying crooked lines.

At suitable points in the pipe line, say about a mile apart, are located stations for charging the tanks of the locomotives. Fig. 15 shows a charging station and the charging device on the locomotive. The charging station consists of a tee, a charging valve, two swing joints, the "ball" of a ball-and-socket-joint, and three short pieces of pipe. The charging connection on the locomotive consists of the "socket" of the ball-and-socket joint, a clamping screw, a check valve, and the necessary pipe connections to the tank.

A flange tee for a charging station is shown in Fig. 16.

The check valve on the locomotive is shown in Fig. 11. The handle is very essential on this valve; if a little dirt lodged under the seat in charging the locomotive all of the air would blow out of the tank before the valve could be fixed. With the handle the disk can be turned to grind out the dirt. The charging valve shown is similar to the check valve, but

with a round end on the stem instead of a hexagon one, and with a long "double-ball" handle. A swing joint is shown in Fig. 17. This, it will be seen, combines a swing joint and two elbows. The use of the split ring enables it to be put together without having the stuffer, rings, etc., large enough to put on over the large end of the elbow.

Fig. 18 shows the ball-and-socket joint made by Deck Brothers, Buffalo, which gives good satisfaction for high-pressure air. It is made of brass and has a screwed instead of a bolted follower. The male half is a nipple instead of an elbow, so it does not require the split ring. An elbow must be used with this swing joint to make it complete for use on a charging station.

Fig. 19 shows the ball-and-socket joint and clamping screw. With the charging station shown the locomotive may stop within about 3 feet on either side of the station, that is, at any point in a distance of about 6 feet. A common form of charging station used in the coal mines of the United States consists of three "Moran" ball joints, a special threaded union to connect the locomotive, a charging valve and a "bleeder," which is a small valve to let the air out of the piping after the charging valve is closed so that the union can be unscrewed with a wrench. As the ball joints permit movement in a vertical as well as in a horizontal direction, they are usually counterbalanced with rope, pulley and weight. With this style of charging station it is necessary to stop within a foot or two. The charging station illustrated herewith does away with the necessity of counterweight, bleeder and wrench, allows greater latitude in stopping, and thus reduces the time required for charging from one or two minutes down to half a minute.

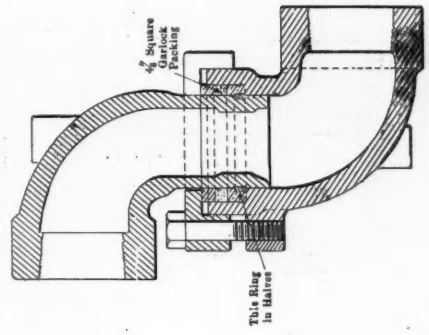


FIG. 17

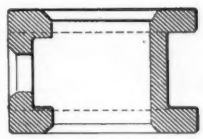


FIG. 16

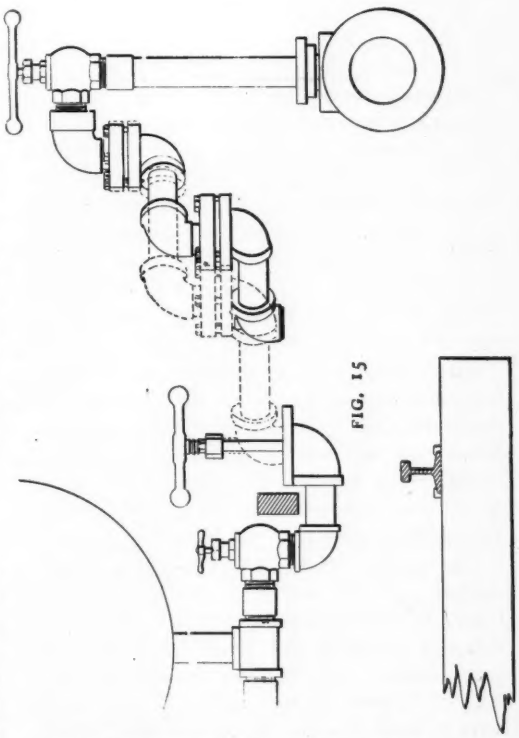


FIG. 15

CHARGING DEVICE, TEE AND SWING JOINT.

LOCOMOTIVE JOINTS AND FITTINGS.

The storage tanks on the locomotives are designed for much higher fiber stresses than would be permissible in a steam boiler. There are no strains due to unequal expansion, no corrosion due to bad water, no danger of low water allowing the plates to be weakened by heat, no such tremendous storage of energy as in the hot water in a boiler, and no chance for a large increase in pressure. For these reasons the tanks are designed for fiber stresses of about 20,000 pounds per square inch. The 36-inch x 10-foot tank shown in Fig. 20 has a riveted joint of 85 per cent. efficiency, and with 800 pounds air pressure

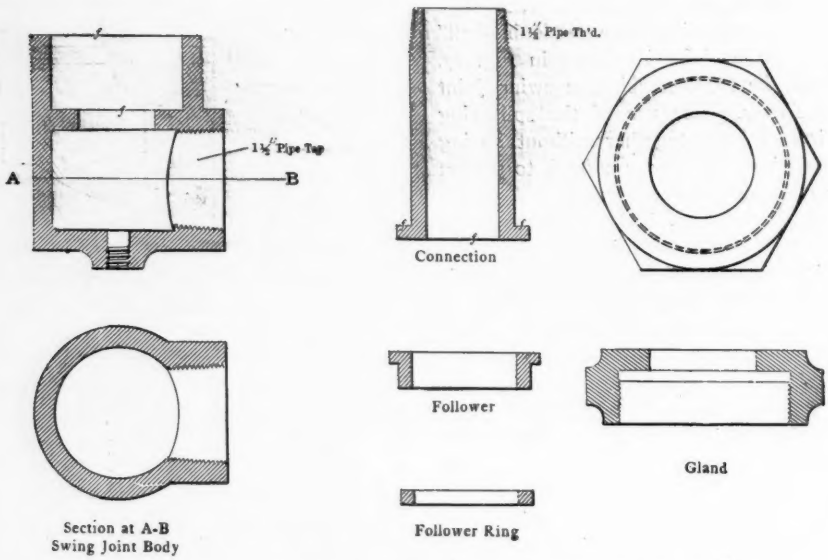


FIG. XVIII. DETAILS OF A 1½-INCH "DECK" HIGH-PRESSURE SWING JOINT

the stress figures out 19,360 pounds per square inch. Tanks 30 inches in diameter with welded longitudinal seams for 1,000 pounds working pressure were made ¾-inch thick, which figures out 20,000 pounds per square inch fiber stress, or, if only 90 per cent. is allowed for the welded joint, 22,222 pounds per square inch. Tanks 32 inches in diameter with welded longitudinal seams for 1,000 pounds working pressure were made 13/16 inch thick, which figures out 19,700 pounds per square inch for a 100-per cent. joint.

These tanks were all made in England and were fine looking pieces of work; heads and manholes were evidently flanged by hydraulic press, and the welded seams were scarcely visible. The tanks with welded longitudinal seams were cheaper than those with riveted longitudinal seams.

The method of fastening the tanks to the saddles is important. At one of the coal mines in Pennsylvania I was told that three different methods had been used on their locomotives. The first locomotive had the saddles secured to the tank by cap screws with straight threads, the second one had cap screws with taper threads, and later ones had taper bolts. The straight threaded cap screws leaked and were finally replaced by taper bolts. The Canadian locomotive had taper bolts put in as shown in Fig. 21. It was not found necessary to even calk a single copper washer.

The stop and reducing valves between the storage and auxiliary tanks are a most vital part of the locomotive. Fig. 22 shows one of these sets of the latest design. It consists of

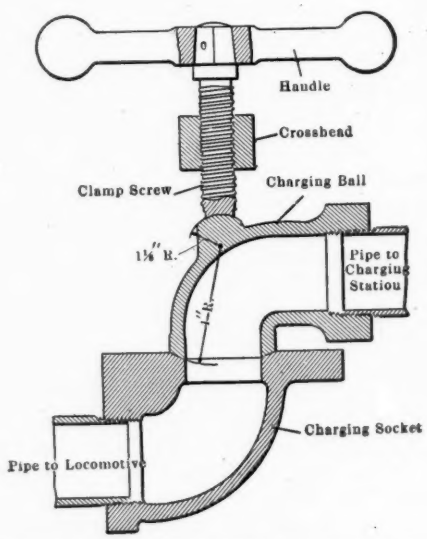


FIG. XIX. BALL JOINT WITH CLAMPING SCREW FOR A CHARGING STATION.

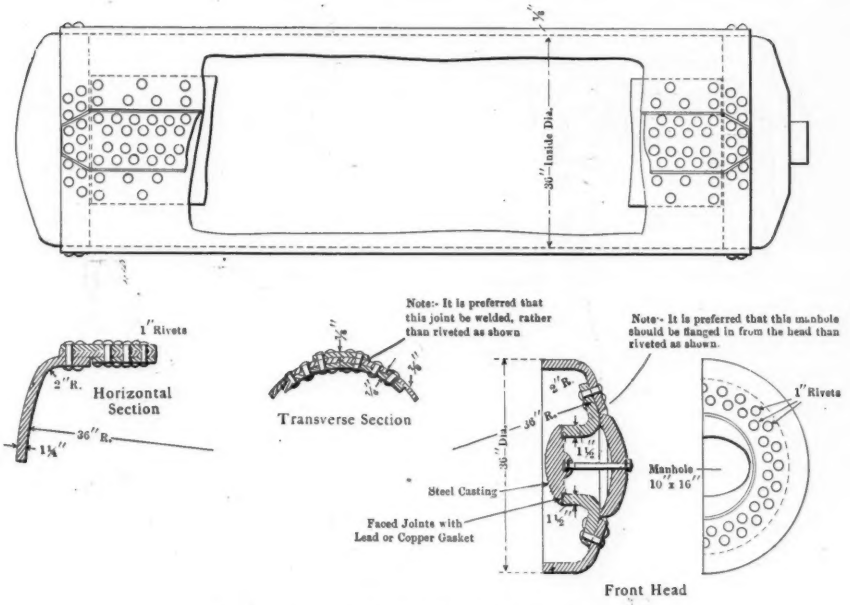


FIG. XX. AIR TANK FOR 800 POUNDS PRESSURE.

a hand stop valve, an automatic stop valve with its auxiliary valve and a reducing valve. Of the set shown in Fig. 22 the Foster Engineering Company furnished the automatic stop valve and the reducing valve, but the hand stop valve and the auxiliary valve were built in the Canadian shops.

The hand stop valve is only used in case the other valves require packing, or minor repairs. It can be used, however, instead of the automatic stop valve or instead of the reducing valve if either of them should be temporarily disabled. The automatic stop valve shuts off the high-pressure air when the pressure rises to 160 pounds in the auxiliary tank, and opens again when the pressure falls to 140 pounds, thus protecting the reducing valve from wire drawing when little or no air is being used. Ordinarily it will close just after the throttle closes and open just after the throttle opens, thus relieving the reducing valve when the locomotive is standing. The reducing valve is perfectly balanced, there being no differential unbalanced area as in the case of an ordinary balanced throttle valve.

It will be seen that this set of valves is of the piston construction throughout; that is, there are no diaphragms. The first valves made by the Foster Engineering Company had diaphragms in all the valves. At several mines in Pennsylvania which I visited there was complaint of diaphragms breaking. The matter was taken up with the Foster Engineering Company, with the result that on

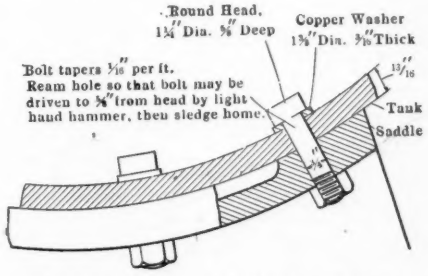

Round Head, 1¼" Dia. ⅝" Deep
Copper Washer 1⅜" Dia. 5/16" Thick
Bolt tapers 1/16" per ft. Ream hole so that bolt may be driven to ⅝" from head by light hand hammer, then sledge home.
13/16"
Tank
Saddle

FIG. XXI. PNEUMATIC LOCOMOTIVE BOLTS.

the Canadian valves they eliminated the diaphragms, first on the auxiliary valve and the automatic stop valve and then on the reducing valve. In reply to a recent inquiry for their opinion as to the value of this change the Foster Engineering Company wrote:

"We agree with you that the piston construction is a radical improvement over the old diaphragm construction for this service. We have noted in the past that where dia-

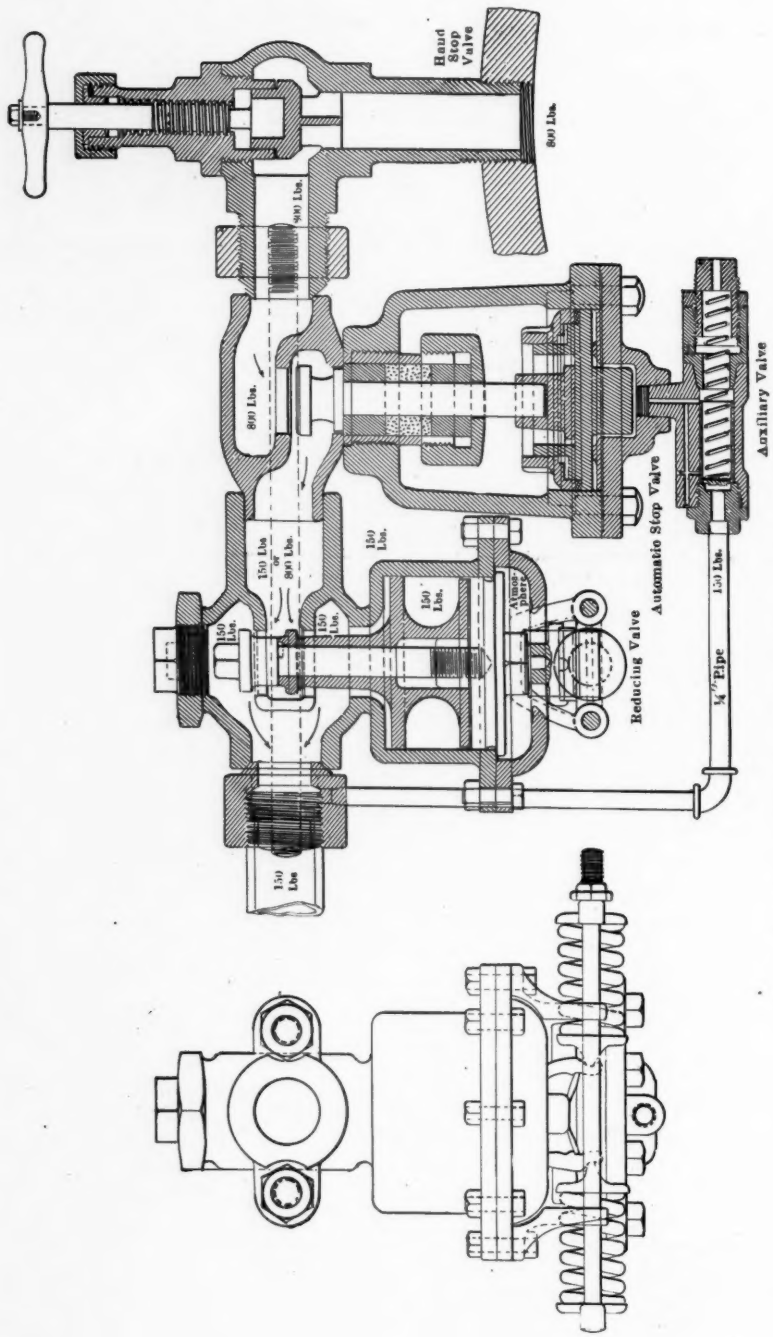


FIG. XXII. PNEUMATIC LOCOMOTIVE STOP AND REDUCING VALVE.

phragms are used there is a tendency to crystallize and destroy the life of the diaphragms, practically throwing the valve, after some little time, out of commission— a condition that is, of course, not experienced in the use of the piston-actuated type. For this

reason we believe the piston-actuated type in actual service will outlast the diaphragm type ten to one."

After passing the reducing valve, the compressed air can no longer be considered as at high pressure, but the style of throttle valve may be of interest. It is shown in Fig. 23, and is of the pilot-valve type; both disks being well guided. It has been found to hold the pressure well, to give good control

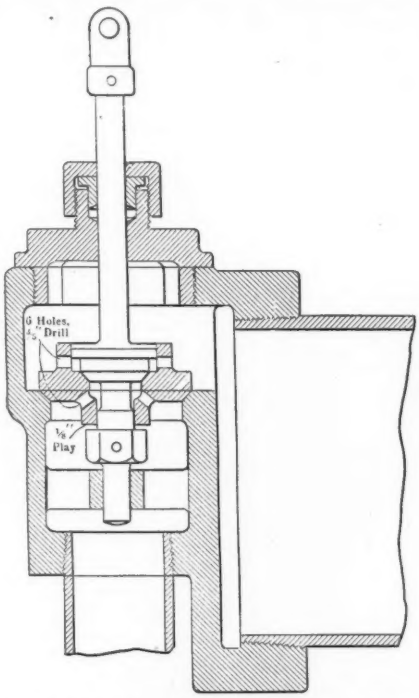


FIG. XXIII. THROTTLE VALVE FOR A PNEUMATIC LOCOMOTIVE.

and to work easily. The body of the valve forms also an elbow and a head for the auxiliary tank.

A few miscellaneous high-pressure fittings are also illustrated. Fig. 24 shows how a coil of copper pipe in a tank is connected to the exterior piping. The fitting shown combines union, elbow, tank connection and connection to the copper tube. The fitting shown was used for only 350 pounds pressure, but would probably be good for 1,000 pounds pressure or more. The manner of connecting to the copper tube is the same as used in automobile fittings for ¼-inch copper tube (see Fig. 25). This form of connection deserves to be better known; it requires neither threading nor soldering of the pipe; is easily connected and will hold almost any pressure. It looks as though it would be a good way to connect lead pipe to faucets.

CONCLUSIONS.

From experience with the joints and fittings described above it appears safe to draw the following conclusions in regard to air piping:

1. The regular taper pipe thread is a very satisfactory permanent joint. In this connection the following quotation from the Crane Company catalog will be of interest:

"The screwed joint, when properly made, has, to the best of our knowledge, given complete satisfaction, and we are now disposing

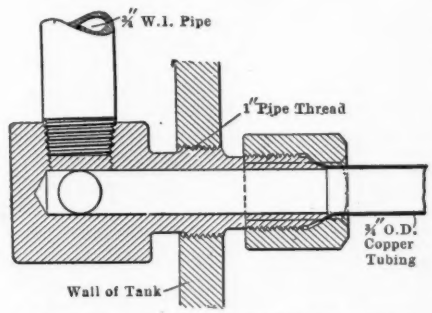


FIG. XXIV. TANK CONNECTION FOR ¾-INCH COPPER TUBE.

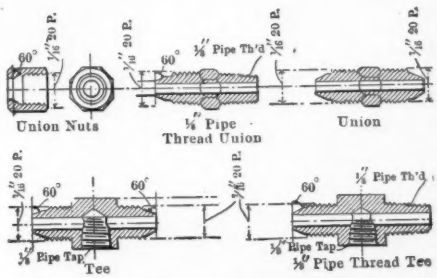


FIG. XXV. UNIONS AND TEES FOR ¼-INCH COPPER TUBE.

of more of these for power-plant purposes than all of the other styles of joints combined.

"Taking up the objection that cutting the thread on pipe weakens it, we will say in explanation of this that the part of the pipe where the thread is cut is always strengthened by the flange or fitting into which the pipe is screwed, and, in many destructive tests

which we have made the pipe has never burst where the thread has been cut, but always burst longitudinally some distance from the thread; nor do we remember of ever having received a complaint of the pipe giving way at the thread.

"We make high-pressure joints as follows:

"The flanges are screwed up by power on a long taper thread cut to a true standard, until the pipe projects through the flange, great care having been taken in the tapping of the flange and the threading of the pipe to the correct size, so that same will screw up to the shoulder in the flange and not expose any part of the thread, which would form a weak point in the pipe line. We also take the greatest care to have the threads perfectly clean, which is one of the secrets of making a tight-screwed joint. This matter, we think, has been overlooked by a majority of mechanics in this class of work. The length of pipe is then placed in the machine and the ends of the same turned off flush with the face of the flange. A light cut is also taken off the face of the flange at the same time to insure its face being perfectly square with the pipe."

2. Fittings should be heavy to permit of screwing the pipe in very tight and to resist deformation under pressure. Crane Company also lay special stress on having screwed flanges of good material and very strong.

3. The number of joints should be kept down to a minimum. It will be noted that practically all of the fittings illustrated are combination fittings, thus reducing the number of joints.

4. Flanged joints and threaded unions should preferably have metal-to-metal joints with narrow faces and may preferably be made ball-and-socket type. Where the end of the pipe must be accessible the loose-threaded flange is a very convenient connection.

5. Valves should preferably be of the angle type, with narrow metal-to-metal joints and with the disk well guided. From the design of the Navy valve it appears possible to avoid the use of stuffing boxes around the valve stems, which is a source of a great deal of leakage with common valves.—Condensed from *American Machinist.*

TRIED TO MAKE AN AIR RECEIVER IN THE SOLID ROCK

A correspondent of *The Mining and Scientific Press* writes:

Some years ago I had occasion to do some development work on a property where the air compressor was run by water power, and during the low-water season there was not sufficient power to furnish air for one drill. The vein, a very irregular one, was in quartzite, close to a syenite and quartzite contact, and in places irregular wedges of this syenite penetrated the quartzite and would cut off the vein, which would be found again on the other side of these intrusive wedges of syenite. At one point, to determine whether or not it was a persistent contact or only a wedge, a drift was run into the solid syenite foot-wall for a distance of about 150 ft. This was at a point some 1,300 ft. from the mouth of the adit, and some 60 ft. from the surface, measured vertically, and this drift for the entire distance appeared to be without a fracture in the rock and, in fact, appeared as one solid block of granite.

Under the conditions as stated, I thought it would be practical to place a concrete dam about 50 ft. back from the tunnel in the drift and then use the remaining 10 ft. of the drift for a receiver in which to store compressed air. The sides, top, and bottom of the drift were carefully trimmed, to remove all loose rock, and a concrete dam was built in the drift; in this dam a large pipe was inserted, both for a man-hole and for pipe connections; after the concrete had set the compressed air was diverted to the supposed receiver; though the dam was well rammed yet the air leaked through it very rapidly. We then turned off the air, removed the man-hole, and placed a coat of neat cement on the inside of the dam, and for 5 ft. back on the top, bottom and sides of the drift; after this set we again turned in the compressed air, and, as far as could be determined, not a particle of air leaked through the dam. We could readily raise the air pressure in this rock receiver to a gauge pressure of about 45 lb., above which point it would increase very slowly. With the small plant it was impossible to obtain a gauge pressure of 50 pounds. Upon the closing of the intake valve the pressure would decrease, and in about 36 hours time the gauge would again register zero.

EXPLOSIVES AND SHOT FIRING

Professor Thompson of Leed's University recently lectured upon the above topic at Ashby-de-la-Zouch.

In one of the coal mines inspection districts they found, he said, that for the year ending December, 1906 there was not a single accident reported from explosives or shot-firing, in spite of the fact that twenty-nine different kinds of explosives were used and somewhere about three million shots were fired, consuming 1⅛ million pounds of explosive.

They might, he said, regard an explosive used in blasting as a heat engine. The charge placed in the borehole compared with the gas and air mixture in a gas engine. When either was fired a great deal of energy was liberated. In the gas engine the hot air expanding against the resistance of the piston drove the engine doing mechanical work; nearly one-fifth of the total heat might be converted into work. In the shothole the tearing apart and rending of the rock replaced the moving, and the gases expanding against the resistance of the rock gave up their heat in the same way as in the engine. Looked at in this roughly general manner, they saw that if all the heat given out by 1 lb. of gunpowder or carbonite when fired could be converted into work, it would be equivalent to a 24-horse power engine working for one minute, while that from 1 lb. of blasting gelatine would be equal to a 60-horse power engine working for one minute. There was one explosive used in the detonators he wished to warn them against—fulminate of mercury. Detonators were not things to be played with, as the Professor showed by telling of two friends who had, by non-appreciation of this fact, each lost half a hand. Professor Thompson described the different fuses, and then came on to deal with the various Government testing stations, speaking of the deficiencies of our own system. There was no absolutely safe explosive for the mine. All the explosives would fire a mixture of fire-damp and air. They must always assume that an explosive fired in coaldust was dangerous, even with a permitted explosive, and then to make it as safe as possible they must try and let the heat of its high temperature be used up in accomplishing the work required of it. The borehole should be well stemmed. At a colliery they must not, of course, have a combustible fuse for igniting the charge, and Professor Thompson dealt particularly with electric fuses—high and low tension. Spark fuses required 4,000 volts to give a spark of $^1/_{12}$ in. The latest magneto gave a voltage of 80 at the highest speed and with slow ordinary driving, 40 volts., the current being .12 and .008 ampéres respectively. A low tension magneto exploder gave 20 volts at good ordinary speed, and at maximum speed could attain 27 volts. The current at low speeds was .8 ampères and at high speeds .97 ampères. Fuses (present primers) with resistances of about 12 ohms. required about ¾ ampères, though some were fired at .4 ampères. The range of the older tension fuses was more sensitive. In high-tension fuses in which the resistance might vary from 50,000 ohms to 6,000 ohms during measurement and with 13 to 36 volts. the current required was $^1/_{300}$ to $^1/_{200}$ ampères. He preferred the series wiring to parallel where a number of shots were to be fired together. In firing they should always see that they had got full power in the battery. Otherwise there would be missfires.

THE COAL AND FREIGHT TUNNELS OF CHICAGO

Under the streets of Chicago are sixty-five miles of tunnels, the extent of which is not appreciated by the people even of Chicago, perhaps because they do not carry passengers. The tunnel system honeycombs the entire down town portion of the city, reaches as far south as Armour and Archer avenues, as far north as Chicago avenue, and as far west as Green street.

Most of this sixty-five miles of tunnel is about six feet wide and 7½ feet high, the roof being arched. Part of this system is made up of what is known as trunk lines, which are twelve feet high and from twelve to fourteen feet wide. The purpose is, if possible, to make deliveries of coal to the large down-town buildings by means of this tunnel system, thus relieving the dealers of the necessity of maintaining expensive teams for doing the work and, in addition, taking that amount of traffic off the street. As soon as the Illinois Tunnel Company, which owns this subway, began to put parts of its line into operation, plans were made with this object in view. The result has been that the company, to-day, has a direct connection with the Chicago & Eastern Illi-

nois railroad and with the Chicago & Alton railway, while coal handling elevators have been put in some of the biggest down-town buildings, among them those of Marshall Field & Co. and the First National Bank.

The company will soon have 250 small locomotives to work under ground and 2,500 of their small cars or lorries, which will be handling all kinds of traffic, but especially mail and coal. Arrangements have been made to increase this equipment as fast as the need arises. The difficulty of making this sort of installation is seen at once when the statement is made that the top of the tunnel is fully thirty-three feet below the ground in all parts of the city. Where the tunnel is only 7½ to eight feet in height this makes the average space between the floor of the tunnel and the street level forty-one to forty-two feet. The company has passed under the Chicago river fourteen times at which places it has dropped down to a depth of sixty-three feet below the average street level. The tunnel, at this depth, is so far under the surface of the ground as to be below all of the sub-cellars of the various establishments.

DIGGING UPWARD.

When it becomes necessary to make a connection with any of the larger buildings in order to put in a coal handling, it is necessary, of course, to burrow up from the tunnel into the basement of the building and then establish some kind of connection which will get the coal conveniently into the fire room. The company has already a number of these elevator plants installed, one being practically a model for all.

The arrangement for handling coal from these cars into the boiler room of a big building is not dissimilar to the arrangement in vogue at the transfer plant of the Dering Coal Company at Peoria, Ill. The car, which has a hopper bottom, comes up to the designated place on the track and dumps its load of three and a half tons of coal into a track hopper. The fuel is fed from there into a bucket conveyor which hoists the coal up to the top of the shaft and it is there turned over to a belt conveyor of some sort located at a height equal to the top of the boiler in the building. The subway car which carries the coal is, under ordinary circumstances, enabled to do double service, because from the level of the floor on which the boiler equipment is located a chute carries the ashes out from the fire room and dumps them into the car just unloaded. By this plan the equipment of the company is able to do double service and consequently gets loads in both directions.

Underneath the tracks of the Chicago and Eastern Illinois and immediately over the tracks of the Illinois Tunnel Company are a number of track hoppers each of which has a storage capacity of 150 tons. Coal, to be delivered into these storage pockets, must, for convenience sake, be shipped in hopper bootom cars. The railroad car is placed immediately above a chute which leads down to the track hopper. This hopper, in turn, has a chute which leads down and opens immediately above the track of the tunnel company. The pressure of the coal and the size of the lower opening make for almost instantaneous loading of the fuel, as is shown by the fact that on a recent occasion three and a half tons of coal were loaded into a tunnel car in two sections.

HOW TO GET A FRANCHISE.

In obtaining the consent to build this tunnel the president of the company, who was interested with a number of friends in an independent telephone, obtained a grant for a telephone subway. He made it appear to the City Council that he wanted to use these subways for the purpose of facilitating the laying of telephone wires underground. At the time the ordinance went through the City Council no suggestion was made of the possibility of handling freight in this subway, the grant merely giving the tunnel company the right to place telephone wires and transmit sounds, signals and intelligence by means of electricity or otherwise. It was soon determined that under the head of intelligence the company could handle both mail matter and newspapers and since the latter came really under the head of freight the operations of the company soon spread from mail matter and the newspapers to carrying package freight and now to the transportation of coarse freight—coal and ashes.

COMPRESSED AIR

AND EVERYTHING PNEUMATIC

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ELECTRO-PNEUMATIC POWER TRANSMISSION

The power problem is *the* problem of industrial achievement and material progress. Cheap and readily available power makes the opportunity of enterprise and industry, and when it is appropriated and employed values are produced and wealth accumulates. All our power coming ultimately, as far as we now know, from the energy diffused by the sun, the function of the entire series of operations and devices this side of the sun by which this power is made to do the work, in detailed aplications, large or small, of the engineer and the mechanic, may be said to be entirely that of transmission. The development, as we term it, of power by the combustion of coal, the generation of steam and the application of its expansive energy to produce forceful mechanical movement, is only a detail of the transmission series. The employment of falling water which has been drawn up by the sun to turn our wheels is only a less tortuous channel of transmission than the other.

Generally, neither of these two beginnings of the familiar lines of transmission bring the power all the way to the actual work without still other means, the first operation being usually a dividing up and distribution of the power of the larger initial units. For this end of the work other agencies come into play, and the most active and prominent—the one in this age insisting upon being first thought of where anything requiring power is to be done—is the electric current. It is scarcely an impertinence now, when electricity is not employed for any new undertaking, for its friends to be inquiring why not. And yet electricity is not best or most effective for every line of power employment. For some important and responsible operations compressed air seems to be, and seems likely to remain, the most desirable and satisfactory; but even here the habit is developing of these two agencies working together and each providing additional employment for the other.

Electricity makes it possible to adapt compressed air economically in many cases and under certain conditions. When, as often happens, the power is transmitted a long distance, and when, after all, it is desirable to use both electricity and compressed air in the final workings, it is not necessary to lay both wires and pipes all the way; and indeed, it would

not be practical to carry pipes to such distances as wires are now quite commonly laid. Let the wires carry the power most of the way from the big water power, and then let the electric-driven compressor be located within a reasonable distance from its work. Circumstances must determine the details of this arrangement, and especially the location of the compressor.

Generally speaking, if a large volume of air is to be used, it is best to install large units in a suitable power house instead of distributing smaller machines here and there for the saving of some lines of piping. The piping should not be made a bugaboo. There is no difficulty in making and keeping it tight, and the piping makes a cheap reservoir for the air. As the air is always used in more or less irregularity, the fluctuations of consumption can be better taken care of in the concentrated plant than in the scattered and isolated units. The electric air drill has made it possible to use electricity as the sole transmitter of power in mining operations. No lines of piping are employed, the wires leading right to the drill pulsator; and this arrangement, and the success of it, has led to the suggestion now current of distributing small electric-driven compressors in different locations in a mine for driving percussion drills of the familiar air-pressure-driven type. The power cost of such an arrangement would be four of five times that of the electric air drill, to do the same work, not to speak of the many other objectionable features.

THE UNCONQUERED AIR

The following, which is a leader from a recent issue of *The Engineer* (London), is well worth reading as a plain statement of the present status and prospects of the aëroplane and its kindred devices.

For many months mechanical flight has held universal attention. The popularity of the dirigible balloon has been displaced by the aëroplane, and the work of Santos Dumont and Spencer is forgotten in the exploits of the Wrights, Farman, and Delagrange. The conquest of the air is proclaimed by journalists, and columns of our daily papers are devoted to a subject which not a decade ago provoked ridicule and contumely. That is a kind of change to which the engineer and the scientist have always been accustomed; the "noble insanity" in them which "creates" what it cannot "find" is accounted real insanity by the thousands who are unable to comprehend the workings of their minds. But in these sudden changes there is always the same lack of balance, the same want of moderate and quiet thinking. From an extreme of disbelief a sudden spring is made into over-belief. The inventor finds himself a preacher at a revival; he effects something that the public deem a miracle, and straightway their want of any belief at all is changed into a belief in everything. They know neither moderation nor reason.

If anyone considers these observations too severe let him look at the papers for the last few weeks and then consider the results that have been actually achieved. Take first the winning of the Deutz Archdeacon prize by Henry Farman in Paris on January 13th. Farman under atmospheric conditions which had to be watched, waited for and seized at the moment, sent word to the judges that he would attempt a flight. The judges assembled, a course was marked out, and the "aviator" started. He made the circuit laid down in the conditions and won the coveted prize. The flight was about one mile long, and he was in the air one and a half minutes! Attempting to repeat his experiment on a later day his machine was wrecked. He had conquered the air by a successful invasion—when the wind's back was turned—lasting one and a half minutes! What the two Wrights have actually done we do not know with any certainty. They have successfully sailed through the air with a self-propelling aëroplane, but how long the flight, how far, how fast we do not know. What we do know is that, like Farman's, their machine finished a journey by a descent of unpremeditated suddenness. Finally, we have the record beating flight of Delagrange. At Rome he circled nine and three-quarter times—note the lack of completeness expressed in the three-quarters—round a rectangular enclosure. The distance he covered was 15 kiloms (9.3 miles), and he was master of the element for 15½ minutes! The next day he essayed to repeat his success; the weather was not so favorable, and his machine also met with an accident. Taking all these official flights together, not one hour has been spent in the element that we are told has been conquered, and the min-

utes of success have only been snatched when the conditions put everything in the hands of the "conqueror." We have shown these facts in the least favorable light to enforce the truth that we have no more right to say these men can fly than the beginner who makes a sudden dash and covers a few yards before he falls off has a right to say he can walk the tight-rope. But we need not tell engineers that we are very far indeed from undervaluing the successes, short and fitful as they are, that have been achieved. A flight of ten minutes in an aëroplane is worth days of doubtful soarings in navigable balloons, and we give very hearty praise and congratulation to the men who have made the flights. But we must remember that the aëroplane is, and from its nature must remain, a very imperfect vehicle for flight. If we turn again to our daily papers we shall find that the admiration of the reported increases with the speed of the aëroplane. Here is a strange perversion of judgment sprung from the motor car and the railway train! The thing to praise in an aëroplane should be slowness. As its speed increases all its other qualities increase in manifold. Its sustaining power and its stability depend upon its velocity; reduce that and it comes tumbling to earth. It is like a cyclist on a tight rope without a pole or a parasol. Let him stop his machine and he falls into mid air. We do not hesitate to say the day will be seen when the biggest prize will be offered to the aviator who takes the longest time in going round the course—the race shall be to the slowest. That is the object which the inventor must keep in view, the object for which he must work. The problem of flight will not be solved so long as a high forward velocity is the only means of maintaining position in the air. Until we can go slow or fast at pleasure, flying will remain nothing more nor less than a sport with a very limited utility for military purposes. It will be impracticable to start or stop with ease, and impossible to manœuvre with the exactness that is required in a "useful" vehicle. Can we imagine the condition of naval architecture if ships were built only on skimming dish lines and sank to the bottom if their speed dropped below 30 knots? The position is precisely the parallel of the aëroplane.

That the aëroplane will sustain weight has been known for very many years; that by careful proportioning and planning it may be made to bear a man through the air has been proved by hundreds of experimenters; that it may be made self-propulsive and self-supporting has now been demonstrated. Aëroplane after aëroplane may now be repeated almost as readily as balloon after balloon. But we shall get little if any further by such repetition. The aëroplane is full of disabilities, and the search for other means of achieving flight must not be neglected.

THE ENGINEER AND THE CONSERVATION OF RESOURCES

By Willard A. Smith.

Engineering has had many definitions—most of which qualify and enlarge rather than actually define. In a very real sense we may speak of it as the science of economy, of conserving the energy, kinetic and potential, provided and stored up by nature for the use of man. It is the business of engineering to utilize this energy to the best advantage—so that there may be the least possible waste. Nature has stored up combustibles in the shape of coal, oil and wood, the force of gravity in running or elevated water, the force of the wind, solar radiation, tidal power, and animal or muscular energy. These are the materials of engineering, to utilize which to the best advantage calls for the best preparation possible for the engineer to attain.

With the lavishness of newness, little recking our rate of development and its terrible destructiveness, we have gone on in this country along the lines of least resistance until the end of some of these resources is almost in sight. The President has called a conference of Governors of States to consider what can be done towards conserving the coal deposits, the forests and the water supply, all of which are disappearing with startling rapidity. The common weal calls for engineers prepared to meet the situation; for men who shall know how to make every possible unit of energy useful by improved machinery and methods; who can substitute other sources of energy for those which are vanishing; and who can plan and organize a general policy looking to the largest immediate returns without sacrificing the future of the race.

Our country calls for such men and they are needed in the councils of the nation. The business man has broken into the preserves of the lawyers in legislative halls and administra-

tive offices. Why should not the "live-wire" engineer be there also? Why should he not be a maker of policies, instead of a mere technician, retained to work disadvantageously under the direction of the incompetent?

We sadly need in public affairs some of these qualities which he must possess and cultivate. The engineer must be an accurate man; he must know his data and his formulas; and his calculations must be exact. He is needed in politics to combat its dishonesty and slouchiness of thought and method. The engineer must be honest with himself—a kind of honesty all too rare. These qualities fit him rarely for the consideration of problems of national import which are not usually considered as engineering.

The engineer's habits of thought, carried into political economy, may make of it a higher grade of engineering. Albert Fink, the great civil engineer, spent his maturest years in organizing and directing the railway traffic associations of the country, eliminating waste and dishonesty and endeavoring so to unify the great volume of transportation that it might give the public the best service at the lowest cost, and yet permit railways to make such earnings as to insure further development. In this work, he often told me, he was still the engineer. He had graduated from one life class to another, finally reaching, as he deemed it, the highest field of engineering.

Such an engineer will not be content with simply estimating the construction possibilities of any proposed physical development. He will examine into the actual necessities for it and the probabilities of adequate return; considering that the public money should not be sunk merely for the benefit of speculators and contractors or to promote the fad of a class of engineers.

For instance, there is now before the country a proposition for the investment of enormous sums in the improvement of waterways. These are advocated by three classes—men having an itch for figuring in the public eye, politicians seeking an issue to justify their existence, and engineers interested in the technical features of the proposed work. So far as I can see, there has been no careful investigation of the traffic which can possibly be developed; and in most cases it is not only now an unknown quantity, but the conditions for future development are utterly lacking. Ought not the ideal engineer to be an economist, who shall dare to say when engineering development ought not to be undertaken as well as when it ought? *From address at installation of Dean Goss, University of Illinois.*

RUNNING A ROCK DRILL

The rock-drill, above other machines, is the most subjected to rough treatment, the more so underground, where, because of the bad light and want of space, and also from the inexperienced hands in which it is often placed it gets more knocking about than is good for any machine, not constructed on the soundest model and of the strongest material.

In some kinds of rock the bit is very liable to stick, and then the workman hammers at it or upon the body of the drill with whatever first comes handy. A blow from a hammer is the quickest way to release a drill, and will do no harm to a first-class machine, but the blow should be given to the steel, and not, as often happens, on the piston rod or machine itself. To illustrate; an instance is given by Davies, who in using machine-drills in a mine in the south of France, where the miners were a hot-headed mixture of Spanish and French blood, had trouble, arising from the men, when the bit stuck, striking the fronthead (stuffing-box) of the drill and often breaking it, perhaps accidentally, perhaps maliciously, since such a break would create a delay arising from the necessity of changing machines. In that particular mine it happened that the miners were much against the introduction of machine labor for stoping. In fact such was their opposition that the drills were set to work under police protection, but, notwithstanding all precautions, the first man who undertook to run one was assassinated, and the roof of the underground superintendent's house was destroyed by dynamite. This opposition arose from their idea that they would be thrown out of employment as soon as rock-drills were set to work.

It is difficult to find and train men well fitted to the work of running a drill. What is wanted is a man of an energetic, ingenious turn of mind, possessed of much patience, who will take pride in overcoming difficulties in his way, and who will not be happy until he has done so. At first, such a man may lose time by puz-

zling over the job, but, once he gets to know his machine, he will not readily be put in a fix. It is always advisable to have a man available to instruct others when they begin this work. As soon as a drill needs repair, or refuses to work, it should be sent to the surface, as it is a loss of time to undertake to repair it underground, and one is liable, in so doing, to lose some of the fittings.

The machine-man must know how to point his holes and how to fix his support where it will enable the drill to command the greatest number of holes. In operation, if a column or shaft-bar is to be used, place a block of wood between the rock and one end of the bar, though a block at each end is always to be preferred. Fix the bar firmly and rigidly between floor and roof or the walls by means of the jack-screw. Now clamp the drill tightly on it in the required position and square off the rock, where the drill is to enter, at right angles to the travel of the bit. This should be carefully attended to, especially in hard fissured rock, since the bit, under the heavy blow, will glance aside, and not cut down the edge of the hole in line with the travel of the bit. This deviation, if not attended to, will gradually carry the bit so much out of line as to waste the whole effect of the blow in friction, whereupon a bit of smaller size must be inserted. In fissured and troublesome rock, when the drill is allowed to get out of line at the start, it will often cause trouble throughout the entire hole, while *a hole well started is half drilled.*

When the face of rock has been squared, and everything is ready for a start, put in the shortest bit, which will permit a good travel of the feed screw, draw out the piston-rod until the piston strikes the bottom of the cylinder, and screw forward the drill until the bit touches the rock, then give the feed-screw a couple more turns. To fix the bit in its chuck all that is necessary is to force back the piston-rod, then draw it smartly forward, striking the bit against the rock. Then tighten the U-bolt nuts. Permit air to blow through the hose to remove any dirt or grit which may have accumulated, close the throttle-valve, pour two tablespoonfuls of oil into the coupling, bend the hose and connect it to the machine. Oil the rotating gear by removing the screw-plug upon the top cover and the machine is ready to start.

Turn air into the hose from the mains, half-open the valve, when the machine will start and at once begin to cut the rock, and, as the bit penetrates the rock, the machine must be correspondingly fed by the feed-screw. When four to five inches have been drilled, turn on full air, pour water freely into the hole and keep turning the screw-feed as the hole advances. When the short drill has cut as deep as it will reach, shut off the air, get the machine back by means of the feed screw, remove the bit and replace it by the next longer one. Strike the first few blows at half-pressure to bring the bottom of the hole to the shape of the drill, then proceed at full speed as far as that bit will allow, when it in turn must be replaced by a still longer one, and so on to the depth desired.

In running a new machine-drill *with steam,* it may happen that it will not start readily, or at first work slowly. This is caused by the unequal heating of the cylinder and will disappear as soon as the machine becomes uniformly heated. When starting either a new machine, or one which has been laid aside, pour a half-pint of coal-oil into it to remove the gum of the old oil, and, after a few minutes' run, oil with a good suitable oil. Keep the machine properly oiled, take care of it, and you will find it the miners' most useful tool, and one which will last for years with trifling repairs.—*Mexican Mining Journal.*

THE BUSINESS OPPORTUNITY

Labor is cheaper now than it was a year ago, although nominally wages are the same. It is cheaper because it is better.

Materials are cheaper than they were a year ago, not for the same reason that labor is cheaper but in the actual prices that must be paid.

Last year the majority of the dealers in building material had all the trade they could handle. This year business has been fair, as shown by the building records, but there is room for a very considerable improvement.

The one great reason why building operations should be undertaken now or why contracts for supplies should be entered into is that they can be made on more advantageous terms.

Materials can be secured for lower prices, will be delivered more promptly and in a more

satisfactory manner than during either 1906 or 1907.

As a general proposition lumber now is being sold for 10 to 15 percent less than during last year. In some cases where the trade is supplied with special woods a reduction to that extent has not been made. However, 10 per cent. probably represents about the general decline in the retail price of building material.

A Cleveland operator has supplied some specific information showing the relative cost of building in 1907 and 1908 which is reproduced herewith:

	1907.	1908.	Percent. of decr'se.
Masonry and grading	$1,329	$944	29.0
Plastering	585	313	46.8
Plumbing	640	500	21.9
Heating	730	570	22.0
Painting	530	400	24.5

The foregoing comparative values represent actual figures secured by a gentleman who wished to build. The 1907 prices were made during the latter part of that year and the 1908 prices this month (June).

It is high time the general public informs itself of this condition of affairs and profits by the opportunity now presented, one which probably will not long be available.—*American Lumberman.*

RECORD DRIVING IN SOUTH AFRICAN MINES

With more rock drills for a given area than anywhere else in the world it might be expected that on the Rand some of the world records would be made. Mr. E. M. Weston, Manager, Rand Collieries, Ltd., Brakpan, Transvaal, contributes the following to a recent issue of the *Engineering and Mining Journal,* which is showing its enterprise by keeping in close touch with South African mining operations.

On the Simmer reef, which is about 4,000 ft. deep, the record for driving established on the Cinderella reef has been lowered. The 15th level was advanced 294 ft. in 61 shifts of 10 hours. The size of the drive along the reef was 7x5 ft. One white man and six Chinese operated three Ingersoll-Sergeant 3¼-in. drills on one bar. One round was drilled and blasted each shift, and the average gained per round was 4.8 ft. Blasting gelatine was employed, and 50 lb. was used to advance 4.5 ft. or 11 lb. per ft. Fifty-nine of the rounds needed 14 holes with the usual three-hole center cut to break them; 100 rounds required only 12 holes.

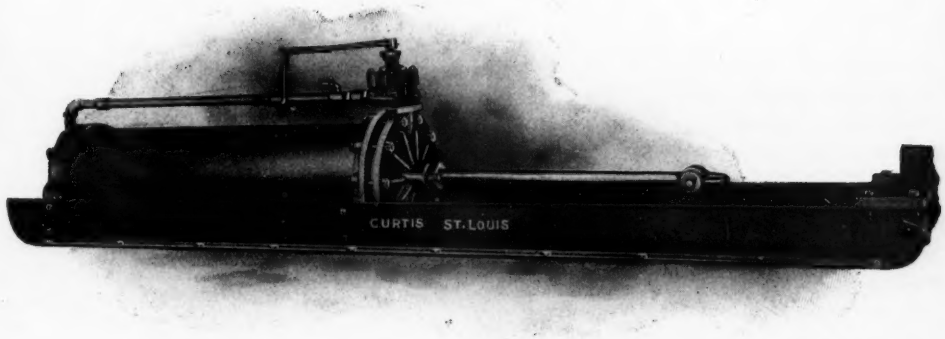
The air pressure at the surface was 80 lb. gage, and owing to the pressure gained at such great depths due to the difference in weight of a column of dense air compressed to 80 lb. in the pipes and the normal air in the mine pipe, friction was balanced and the air was supplied to the machines themselves at 80 lb. This gain in air pressure at about 4,000 ft. equals 10 lb. per sq. in. Water was laid on, and an arrangement was also made whereby the water could be turned into the air pipe, making a spray after blasting and at once cooling the drive and laying the dust.

In comparing these results with those gained in adit driving in America it must be borne in mind that these drives are not straight, that mechanical haulage is not used and that the ground is generally harder and requires more holes and larger quantities of more powerful explosives, while the smaller size of the excavation does not give room for an economical arrangement of holes.

A COAL MINE TIMBER PULLER

The half-tone shows a device of the Curtis & Company Manufacturing Company, of St. Louis, by means of which compressed air is employed for removing timbers from the depleted sections of coal mines to be used elsewhere. The air used is quite inappreciable in comparison with that required for rapidly operating machines, and the saving in timbers will pay for the rig in a short time.

Scarcely any explanation is required. An air cylinder is mounted upon steel skids which can be temporarily secured to track ties or otherwise braced for the pull. The end of the piston rod carries a clevis to which the chain is attached. The chain passes through a guide at the front end of the skids and may lead off in any distance and also at a considerable angle, so that a number of pulls may be made for each locating of the puller. The air supply may be led to the apparatus by the smallest hose in use. The air valve is attached to the front cylinder head so that the operator is always in position to watch the pull. The valve may be opened as gently as may be desired for either movement of the piston and is self-closing when released.



A COAL MINE TIMBER PULLER

A LARGE TROUBLE FROM A LITTLE LEAK

In an enumeration of various experiences of a trouble hunter in a recent issue of *The Contractor* the following occurs:

A Western concern sold a Corliss steam driven air compressor of 2,000 cubic feet capacity. It was set up and started to the entire satisfaction of buyer and seller. After the compressor had been in operation about a month the manufacturers were notified that it failed to regulate and was workng in a very unsatisfactory manner. An expert was requested to come and look into the matter at once. The trouble hunter found everything in perfect order so far as appearances went, but the regulation certainly was poor, and the air pressure varied greatly without apparent cause. Upon closing down in the evening the valve gear was examined, but the cause of the trouble could not be found. Next day's search was equally fruitless. As a forlorn hope the air regulator was taken apart and examined. Nothing could be found upon minute examination that could have caused any trouble. Yet, strange to say, when the regulator had been re-assembled the compressor ran with perfect regulation as if it were working for a prize. The trouble hunter looked wise and said nothing, though he went home mystified. Two months later he was called back again by a repetition of the former trouble. This time before taking the governor apart a most painstaking investigation was made. It was found at last that the air cylinder of the governor, which was connected with the receiver by a quarter-inch pipe, had a leak at the joint, which was made with a cap, so minute that the air blowing through it was not noticed. Yet the quarter-inch pipe not being large enough to take care of the leak without a reduction in pressure, any change in pressure in the receiver did not have its proper effect on the air cylinder of the governor. When this minute leak was stopped the compressor worked satisfactorily and has given no further trouble.

THE LIMIT IN SHAFT SINKING

It may fairly be said that the technique of shaft sinking has undergone such great improvements in recent years, that it is now probably quite equal to any demands that can be made upon it for some time to come. The deepest shafts in the world are in the copper mining district of Lake Superior, where there are at least two close upon 5,000 ft. in depth; with the exception of this district, of a few shafts in the Bendigo district of Victoria, a few at Johannesburg, and some in the Przibram mines in Bohemia, it may be said that there are practically no shafts in metal mines over 3,000 ft. deep, so that the ability to reach considerably greater depths than have hitherto been obtained in most mineral fields may be taken for granted. Indeed, as far as the actual sinking is concerned, there would probably be no serious difficulty in sinking a shaft 10,000 ft. deep, provided that it could be known with certainty that a deposit of ore would be met with of sufficient value to recoup the outlay incurred in such a sinking; in other words, the main problems connected with deep sinking are economic rather than technical. Apart from the difficulties of hoisting and pumping, the main obstacle to very deep working will probably be the effect of the

high temperatures that are met with at such depths upon the workmen employed. Men seem to feel the effects of moist heat when the wet bulb registers about 75 degs. Fahr., and must then commence to strip so as to expose a greater surface of the skin for evaporation, and the limits of working power seem to be reached at about 100 degs. Fahr in a moist atmosphere. It may, however, be urged that the artificial cooling of working places is neither difficult nor costly, and that with the increasing employment of mechanical devices underground, the amount of physical exertion required from the miner is continually diminishing.—Prof. Henry Louis, "James Forrest" Lecture, Institution of Civil Engineers.

COMPRESSED AIR OPERATES THE VACUUM CLEANER

In cleaning cars by the direct action of compressed air the seats and cushions must be removed from the car and blown out. The blowing scatters the dirt and allows some of it to remain in the cushions. If the compressed air jet is used inside the car for blowing out the dirt, the dust and dirt are simply blown from one seat to another and not removed from the car. The vacuum cleaner removes all the dirt from seats and cushions by suction, carries it outside the car through the hose and deposits it in the receiving tank, all without raising a particle of dust in the car.

The apparatus consists of a dust collecting tank so arranged internally as to separate the dust from the air, an air jet vacuum producer mounted on top of the tank, special vacuum hose for conveying the dirt from the car to the vacuum tank and the sucking nozzles. These are made of metal and have from one to three slots in each through which the air is drawn with a rush bringing the dust and dirt with it. The vacuum producer is connected with it. The vacuum producer is connected to the compressed air supply (either the pipe-line or the air brake reservoir on the car) by means of a compressed air hose. The vacuum hose is attached to the side of the tank, and the other end with the tools attached is carried into the car. The compressed air is turned on and regulated by the valve on the vacuum producer until the proper vacuum is obtained. The cleaning tools are then passed over the seats and other parts to be cleaned until the dirt is removed.

NOTES

A small balloon sent up by Prof. Rotch of Blue Hill observatory, near Boston, registered an altitude of 46,680 feet, and a temperature of 111 degrees Fahr. Whether the lowest temperature was coincident with the greatest altitude did not appear.

Diamonds, though extremely hard, are also very brittle and are easily fractured by a sharp blow. If, however, a good diamond is placed between the jaws of a hydraulic press, and the pressure is applied slowly and without jerk, the jaws may be made to meet without the slightest injury to even the edges of the diamond, a perfect impression of which will be found in the hard steel jaws. This interesting experiment, illustrating at once the hardness of one material and the flow of another material also considered hard, doubtless many readers will be trying for themselves.

The R. D. Nuttall Company, of Pittsburg, announces the establishment of a new department to be devoted exclusively to the manufatcure of gears and pinions for air compressors. This company has for some time been supplying gears and pinions for all the standard makes of air compressors. It is owing to the rapidly growing demand for compressed air in a number of important industries that a special department was found necessary. The department will be equipped to turn out gears and pinions for the standard types of compressors upon short notice, and to better accommodate the users of compressors will carry a complete assortment from which immediate shipment can be made.

There died a short time ago in Grass Valley, Cal., a noted character who was widely known in that State for his long and persistent work as a miner under adverse circumstances. He was a pioneer and lost his sight by a blast some 56 years ago. Despite his affliction, Hyman Clendenning continued work as a miner until quite lately, when old age and ill health stopped him. He had a theory about the existence of a rich gravel channel underlying a certain tract of land, and for many years carried on work alone in a tunnel to develop this channel. Quite recently the Jenny Lind Mining

Company struck this channel and is finding it extremely rich. While his theory was proven, it was of no benefit to the blind miner, who had been unable to get assistance to carry his tunnel to completion. So persistent was he, however, that he worked alone, as stated, for many years, and did his mining work with skill, notwithstanding his blindness.

Extensive experiments have been carried out on the Austrian government railways with automatic vacuum brakes on freight trains. A train composed of 70 cars loaded with coal, and weighing 44,000 pounds each, was fitted with automatic brakes. Numerous trials were carried out with this train on lines having different road conditions, and the trials were repeated on a line with gradients of from 3 to 3.1 per cent. In this experiment the train was composed of 70 freight cars and 5 passenger cars, interspersed for observation purposes. Twenty-nine of the total 75 cars carried load, and 46 carried no load. The weight of the train, including locomotive and tender amounted to 1,201.7 metric tons (1,322 short tons) and the total length of the train was 2,620 feet, or nearly half a mile. The results are said to have been very satisfactory. Considering the length of the train, the brake valve on the last car came in action very rapidly, only 2.2 seconds being required for the brakes to be applied on the last car after they had been applied on the locomotive.

Liquir air is used to some extent for blasting purposes in a few German coal mines. It was first used in combination with other materials, but is now used alone. Its explosive power depends upon its property of turning suddenly into vapor at an elevated temperature. If the vessel holding the liquid air is sufficiently tight, a high explosive power is attained. For this reason vessels with a small opening are used for storing it. This characteristic makes it necessary to place the cartridge in place before it is loaded. The cartridges are made of thick phosphor bronze and are loaded so that the pressure reaches 80 lbs. per sq. in. The explosion takes place in 6 or 8 min. after loading. About 30 tons of coal are broken by one shot. The coal falls in blocks about 2 ft. in cercumference. A heavier loading of the cartridge would cause the coal to be broken into slack.

LATEST U. S. PATENTS

Full specifications and drawings of any patent may be obtained by sending five cents (not stamps) to the Commissioner of Patents, Washington, D. C.

JUNE 2.

889,290. WINDMILL. ALBERT J. ANDERSON, Batavia, Ill.

889,398. ROTARY COMPRESSOR. CASSIUS C. PALMER, New York, N. Y.

889,477. Motor Mechanism. AUSTIN E. MILLER, Cheney, Wash.

1. In mechanism of the class described, a reservoir for storing gases under pressure, an explosion chamber in communication therewith, an air compressing cylinder, a plunger therein, a motor having an inlet port connected to the reservoir, means for operatively connecting the motor to the plunger, and a liquid fuel measuring means controlling communication between the pumping cylinder and the explosion chamber.

889,547. DIE-CASTING APPARATUS. ALBERT G. RAUH and LAWRENCE OSLEN, Indianapolis, Ind.

1. In a die casting apparatus, the combination with a crucible, a charging cylinder, means connecting said charging cylinder and said crucible, and a die situated under and contacting said charging cylinder, of a fluid pressure and a molten metal supplying means, and a lever common to both said means whereby the molten metal and the fluid pressure are alternately admitted into and exhausted from said charging cylinder.

889,794. VALVE MECHANISM FOR WATER-ELEVATORS. J. L. LATTA, Hickory, N. C.

1. In apparatus of the class described, a main air valve, a casing within which the valve is arranged, a compressed air pipe connected to the casing, a valve for controlling the movement of the main valve, an air driven motor for actuating the controlling valve, means for connecting the motor to a source of compressed air supply under a pressure greater than that supplied to the main air valve, and means for directing a portion of the exhaust from the motor into said pipe.

889,701. APPARATUS FOR DISINTEGRATING FUEL-OIL. HARRY LUCKENBACH, San Francisco, Cal.

In an appartus of the character described, the combination with a hollow body, of a nozzle therein for discharging compressed air, a pipe for feeding oil opening in front of said nozzle, a pipe connected to said hollow body and a coiled spring in said pipe tapering towards its discharge end, and made with flattened surfaces, substantially as described.

889.883. WIND-OPERATED DYNAMO. EMIL J. JOHNSON, Madrid, Iowa.

JUNE 9.

889,992. VACUUM-BOTTLE AND CASING. GARRY P. VAN WYE, New York, N. Y.

890,012. PERCUSSION ROCK-DRILL. ROBERT ANDERSON, Johannesburg, Transvaal.

890,057. COMBINATION GAS AND WATER VALVE. HERBERT S. HUMPHREY, Kalamazoo, Mich.

890,065. ROCK-DRILL. MOSES KELLOW, Penrhyndendraeth, England.

890,108. PNEUMATIC RIVERTER. WILBUR H. VAN SICKLE, Philadelphia, Pa.

890,289. OXYGEN-CUTTING APPARATUS. HENRY P. MERRIAM, New York, N. Y.

890,310. SANDING APPARATUS FOR TROLLEY CARS AND THE LIKE. CHARLES SNYDER, Manayunk, Pa.

In a sanding apparatus, a sand box, a delivery pipe leading into one end thereof, a partition secured to said end of the box so as to have its lower end registered with said pipe, the top end of the partition terminating below the top of the box so as to provide a constricted passage in conjunction therewith, a pair of horizontal air pipes leading into the opposite end

of the box, said pipes being spaced apart and being arranged so that one is adjacent the top of the box, and the other is adjacent the bottom of the box, and means for supplying compressed air to each of said pipes.

890,439. ACETYLENE-GAS GENERATOR. JAMES E. MCINTIRE, Columbus, Ohio.

890,488. PNEUMATIC VALVE-ACTION. HARRY BAINTON, New York, N. Y.

890,516. AIR COOLING AND HUMIDIFYING APPARATUS. JAMES KELLY, Providence, R. I.

890,546. ROCK-DRILLING EXPLOSIVE-ENGINE. AUGUST B. WITTMAN and GEORGE L. RORK, Denver, Col.

JUNE 16.

890,620. PROCESS AND APPARATUS FOR INJECTION OF LIQUID FUELS INTO INTERNAL-COMBUSTION ENGINES. RUDOLPH DIESEL, Munich, Germany.

1. A process of injecting fuel into internal combustion engines which consists in injecting a jet of liquid fuel previously oxygenated, into a body of compressed air in the compression space of the engine.

890,671. PNEUMATIC WHEEL FOR VEHICLES. BRYCE J. MACAULAY, Eastbourne, and JAMES A. F. HALL, Hampden Park, near Eastbourne, England.

890,808. ROD-PACKING FOR ROCK-DRILLS. WILLIAM L. SMITH, Columbus, Ohio.

890,893. WIND-DRIVEN PUMP. EUGENE EGGLESTON, Columbus, Ohio.

890,930. AIR-BRAKE SYSTEM. HAROLD ROWNTREE, Chicago, Ill.

890,931. AIR-BRAKE-CONTROL MECHANISM. HAROLD ROWNTREE, Chicago. Ill.

890,932. AIR-BRAKE EQUIPMENT FOR CARS. HAROLD ROWNTREE, Chicago, Ill.

890,933. BRAKE MECHANISM. HAROLD ROWNTREE, Chicago, Ill.

890,978. PNEUMATIC DRILL. MARTIN HARDSOCG, Ottumwa, Iowa.

890,987. NOZZLE FOR PNEUMATIC CLEANING APPARATUS. ARTHUR W. KINDEL, Denver, Colo.

890,994. APPARATUS FOR UTILIZING THE FORCE OF THE WAVES OF THE SEA. PETER MORICE, Neutral Bay, North Sydney, New South Wales, Australia.

1. In an apparatus for utilizing the force of the waves of the sea, a platform A, one or more cylinders, open at both ends, pendent therefrom, means for automatically controlling the position of the cylinders by the tide, easy fitting pistons or disks within the cylinders, piston rods rising vertically from the cylinders, and means for connecting the piston rods with compression pumps, as and for the purpose set forth.

891,026. VACUUM-PUMP. JOSEPH ZEITLIN, Kensington, England.

891,144. TERMINAL FOR PNEUMATIC-TUBE SYSTEM. CHARLES H. BURTON, Washington, D. C.

891,180. AIR-VALVE FOR RADIATORS. FRED W. LEUTHESSER, Chicago, Ill.

891,211. AIR-GUN. AUGUSTUS H. M. DRIVER and GEORGE NORMAN, Small Heath, near Birmingham, England.

JUNE 23.

891,290. BLOWING ENGINE OR PUMP. GUSTAV B. PETSCHE, Philadelphia, Pa.

2. In a blowing engine or compressor the combination with the cylinder having the chambered end members connected by a hollow central member, said central member having ports formed in it which serve to pass the fluid pumped or compressed from the cylinder into the receiving space formed by the chambers in said end members and the interior of said hollow central member, of the annular reciprocating piston in said cylinder and surrounding said central member, and the outlet valve mechanism controlling said ports located in said hollow member.

891,299. PNEUMATIC STRAW-STACKER. SHERMAN B. SMITH and HARRY W. SMITH, Hamilton, Ontario, Canada.

891,324. TERMINAL FOR PNEUMATIC-TUBE SYSTEMS. CHARLES H. BURTON, Washington, D. C.

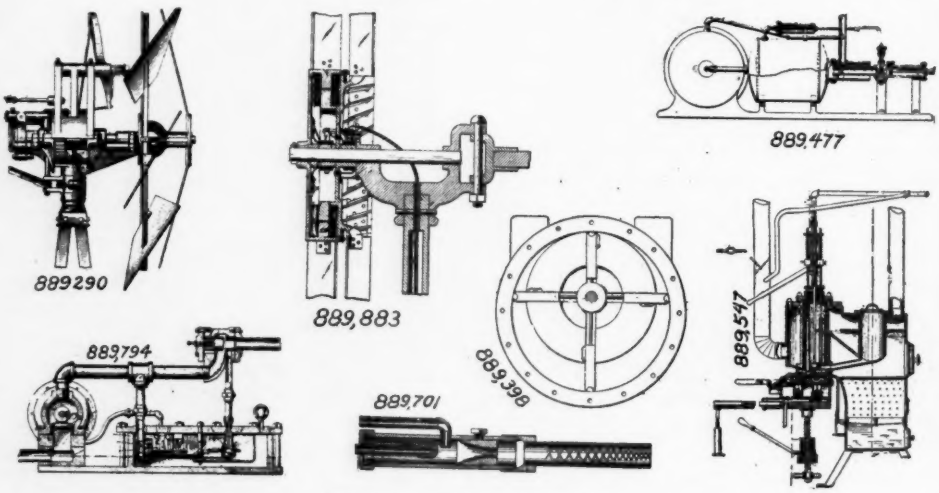
891,341. MEANS FOR AUTOMATICALLY STOPPING TRAINS. GEORGE W. HUNT and JERRY KINNEY, Pocatello, Idaho.

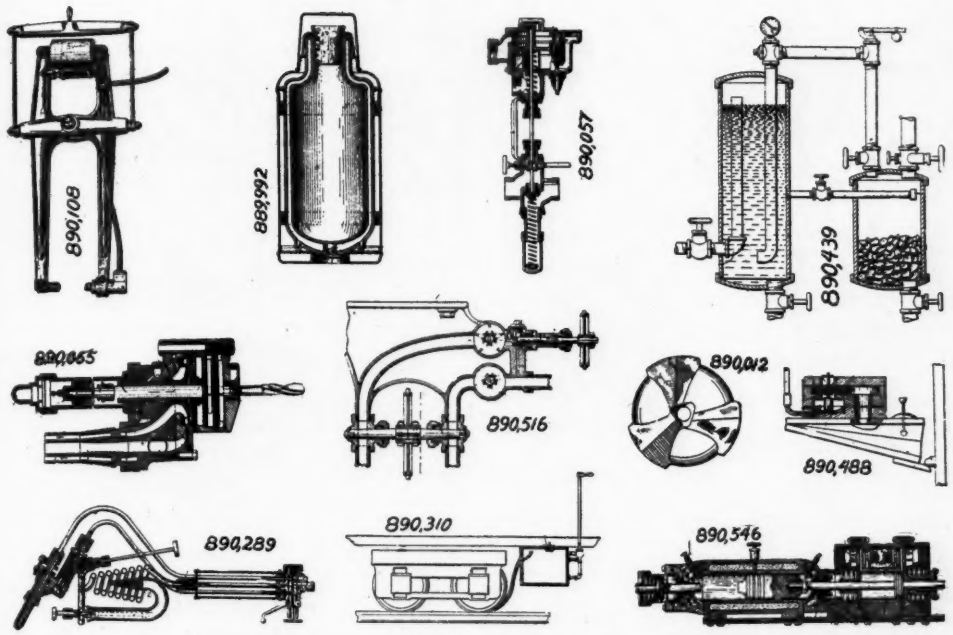
1. The combination with a truck including an air brake mechanism, of an open-ended tampion holder having communication with the air-brake mechanism and containing a tampion fusible in the event of a hot box to permit of the escape of the air from the air brake mechanism.

891,472. VALVE FOR OPERATING ROCK-DRILLS. GEORGE A. FOWLER, Georgetown, Colo.

891,473. TUNNEL - DRIVING MACHINE. GEORGE A. FOWLER, Georgetown, Colo.

891,675. PNEUMATIC ADJUSTER FOR ANGLE-COCKS ON TRAIN-PIPES. WILLIAM S. DE CAMP, Chillicothe, Ohio



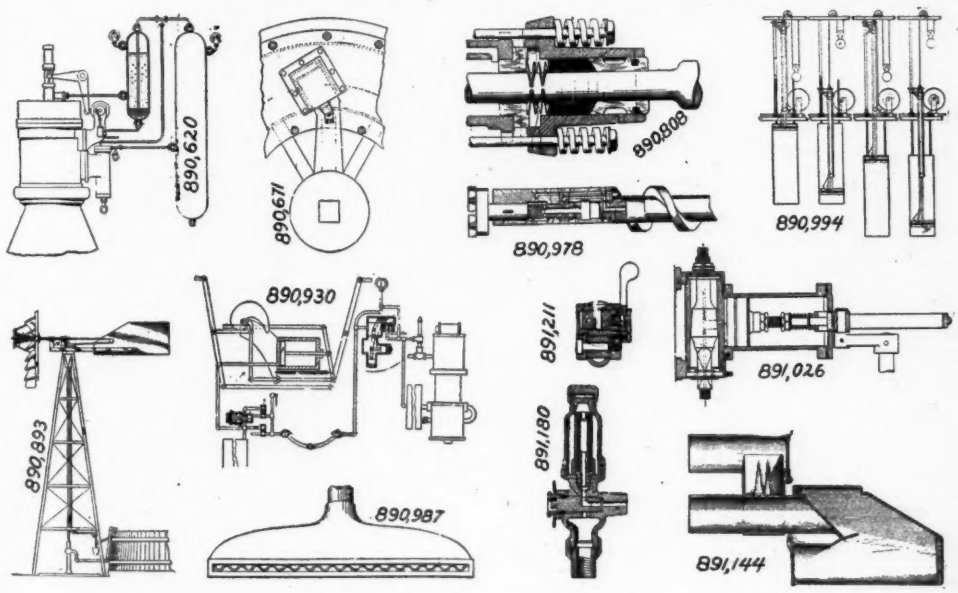


PNEUMATIC PATENTS, JUNE 9.

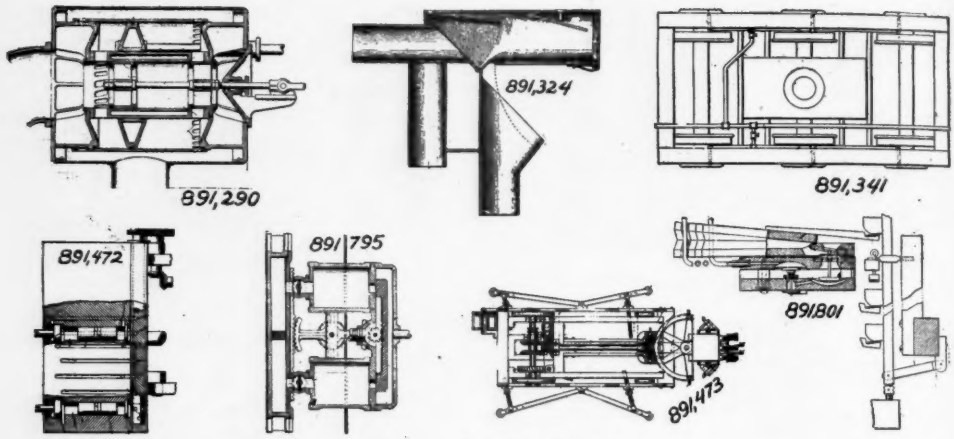
891,676. MEANS FOR CONTROLLING PNEUMATIC SIGNAL-PIPES ON RAILROAD-TRAINS. WILLIAM S. DE CAMP, Chillicothe, Ohio.

891,795. APPARATUS FOR STEERING STEAMSHIPS AND OTHER VESSELS. JOHN S. CLARKE, Cleveland, Ohio.

1. A steering mechanism for vessels operating with a liquid control and fluid pressure thereon comprising a quadrant shaped chamber adapted to be filled with liquid, a rudder shaft therein and a piston fixed on said shaft, in combination with means to operate said piston comprising a set of expansion chambers adapted each to be partially filled with liquid and pressure fluid respectively, passages connecting said cylinders with said piston chamber on opposite sides of said piston and a valve for each of said pas-



PNEUMATIC PATENTS, JUNE 16.



PNEUMATIC PATENTS, JUNE 28.

sages, pressure fluid inlet openings to the top of said expansion chambers and a slide valve to control said openings, and means to operate all said valves simultaneously comprising a rotatable member adapted to be operated by a cable and an arm controlled thereby, whereby the flow of liquid to and from said piston chamber and the flow of pressure fluid to and from said cylinders, respectively, are brought under a single control.

891,801. MUSICAL-DEVICE PNEUMATIC APPARATUS. ROBERT A. GALLY, Brooklyn, N. Y.

JUNE 30.

891,808. AUTOMATIC DRAIN-COCK FOR AIR-BRAKES. FREDERICK W. ADAMS, Selma, Iowa.

891,830. METHOD OF FILLING MATTRESSES. FERDINAND FRANKE, Clark county, Ind.

1. The herein described method of forming mattresses which consists of directing an air blast into the tick of the mattress to inflate it and discharging the filling material into said tick along with said air blast.

891,831. PNEUMATIC HAMMER. JOSEPH FREDERICK, Stroudsburg, Pa.

891,858. BLOWING-ENGINE OR COMPRESSOR. GUSTAV B. PETSCHE, Philadelphia, Pa.

892,082. ROCK-DRILLING MACHINE. WILLIAM PRELLWITZ, Easton, Pa.

892,098. AIR-COMPRESSOR. JAMES THORNTON, Jr., and JAMES THORNTON, Sr., Duquoin, Ill.

892,122. FLUID-PRESSURE BRAKE MECHANISM. JOHN H. BLEOO, Brooklyn, N. Y.

892,123. FLUID-PRESSURE BRAKE MECHANISM. JOHN H. BLEOO, Brooklyn N. Y.

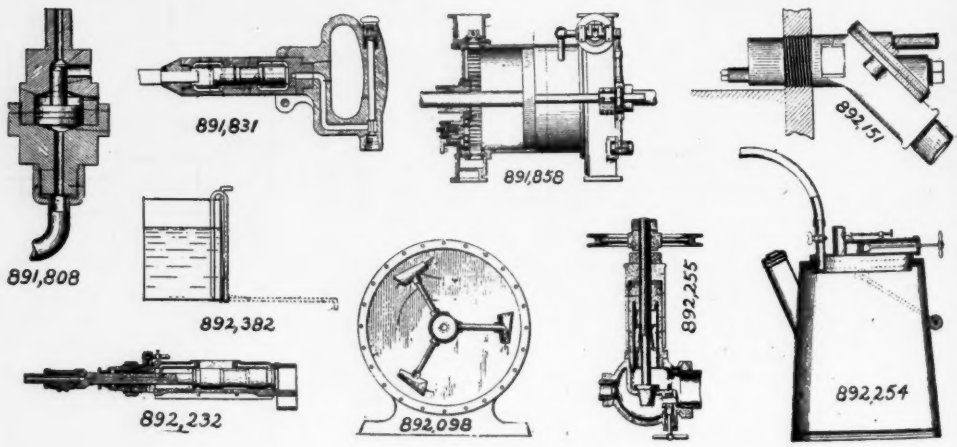
892,151. SANDER. JOHN H. HANLON, Somerville, Mass.

1. In a pneumatic track sander, the combination of a sander-body comprising an elbow and provided with a clean-out opening, a cover for said clean-out opening and an air nozzle passing through the said cover and lying on the floor of the interior of the sander-body.

892,254. MILKING-MACHINE. EDWARD HANSON, Kane, Pa.

892,260. COMBINED STREET SWEEPER AND CLEANER. HENRY A. HUBER, Winnipeg, Manitoba.

892,382. SIPHON DEVICE FOR WITHDRAWING LIQUIDS FROM VESSELS. ALBERT W. OMOND, Bendigo, Victoria, Australia.



PNEUMATIC PATENTS, JUNE 30.